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THE WILLAMETTE BASIN COMPREHENSIVE STUDY OF WATER AND RELATED L--ETC(U)
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WILLAMETTE BASIN

COMPREHENSIVE STUDY

Water and Related Land Resources

APPENDIX E

FLOOD CONTROL

WILLAMETTE BASIN TASK FORCE - PACIFIC NORTHWEST RIVER BASINS COMMISSION

1969

(6) (1)

The WILLAMETTE BASIN

COMPREHENSIVE STUDY of

Water and Related Land Resources

APPENDIX E

FLOOD CONTROL

410 072

WILLAMETTE BASIN TASK FORCE - PACIFIC NORTHWEST RIVER BASINS COMMISSION

(11) 1969

(12) 187p.

CREDITS

This is one of a series of appendices to the Willamette Basin Comprehensive Study main report. Each appendix deals with a particular aspect of the study. The main report is a summary of information contained in the appendices plus the findings, conclusions, and recommendations of the investigation.

This appendix was prepared by the Flood Control Committee under the general supervision of the Willamette Basin Task Force. The committee was chaired by the Corps of Engineers and included representation from the following agencies:

- Federal Water Pollution Control Administration
- Bureau of Reclamation
- Geological Survey
- Soil Conservation Service
- Forest Service
- Weather Bureau
- Oregon State Department of Commerce
- Oregon State Engineer
- Oregon State Water Resources Board
- University of Oregon - Bureau of Governmental Research and Service

ORGANIZATION

PACIFIC NORTHWEST RIVER BASINS COMMISSION

Columbia Basin Inter-Agency Committee until 1967

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Federal Power Commission
Health, Education and Welfare

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C. Economic Base
D. Fish and Wildlife
E. Flood Control
F. Irrigation
G. Land Measures and Watershed Protection
H. Municipal and Industrial Water Supply
I. Navigation
J. Power
K. Recreation
L. Water Pollution Control
M. Plan Formulation

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The Willamette Basin Comprehensive Study has been directed and coordinated by the Willamette Basin Task Force, whose membership as of April 1969 is listed above. The Task Force has been assisted by a technical staff, a plan formulator, and a report writer - Executive Secretary. Appendix committees listed on the following page carried out specific technical investigations.

APPENDIX COMMITTEES

Appendix-Subject		
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M - Plan Formulation	Plan Formulator - Chairman:	USCE, USDA, USDI, OSWRB

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FWPCA - Federal Water Pollution Control Administration
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USBLM - Bureau of Land Management
USBM - Bureau of Mines
USBOR - Bureau of Outdoor Recreation
USBR - Bureau of Reclamation
USBSF&WL - Bureau of Sport Fisheries and Wildlife
USCE - Corps of Engineers
USDA - Department of Agriculture
USHEW - Department of Health, Education and Welfare
USDI - Department of Interior
USDL - Department of Labor
USERS - Economic Research Service
USFS - Forest Service
USGS - Geological Survey
USNPS - National Park Service
USSCS - Soil Conservation Service
USWB - Weather Bureau

OSBH - Oregon State Board of Health
OSDC - Oregon State Department of Commerce
OSDF - Oregon State Department of Forestry
OSDG&MI - Oregon State Department of Geology and Mineral Industries
OSE - Oregon State Engineer
OSFC - Fish Commission of Oregon
OSGC - Oregon State Game Commission
OSHD-PD - Oregon State Highway Department - Parks Division
OSMB - Oregon State Marine Board
OSS&WCC - Oregon State Soil and Water Conservation Committee
OSWRB - Oregon State Water Resources Board
OSU - Oregon State University
PSC-PR&C - Portland State College - Center for Population Research and Census Service
UO - University of Oregon
LCPD - Lane County Parks Department
OCPA - Oregon County Parks Association
POP - Port of Portland

BASIN DESCRIPTION

Between the crests of the Cascade and Coast Ranges in northwestern Oregon lies an area of 12,045 square miles drained by Willamette and Sandy Rivers--the Willamette Basin. Both Willamette and Sandy Rivers are part of the Columbia River system, each lying south of lower Columbia River.

With a 1965 population of 1.34 million, the basin accounted for 68 percent of the population of the State of Oregon. The State's largest cities, Portland, Salem, and Eugene, are within the basin boundaries. Forty-one percent of Oregon's population is concentrated in the lower basin subarea, which includes the Portland metropolitan area.

The basin is roughly rectangular, with a north-south dimension of about 150 miles and an average width of 75 miles. It is bounded on the east by the Cascade Range, on the south by the Calapooya Mountains, and on the west by the Coast Range. Columbia River, from Bonneville Dam to St. Helens, forms a northern boundary. Elevations range from less than 10 feet (mean sea level) along the Columbia, to 450 feet on the valley floor at Eugene, and over 10,000 feet in the Cascade Range. The Coast Range attains elevations of slightly over 4,000 feet.

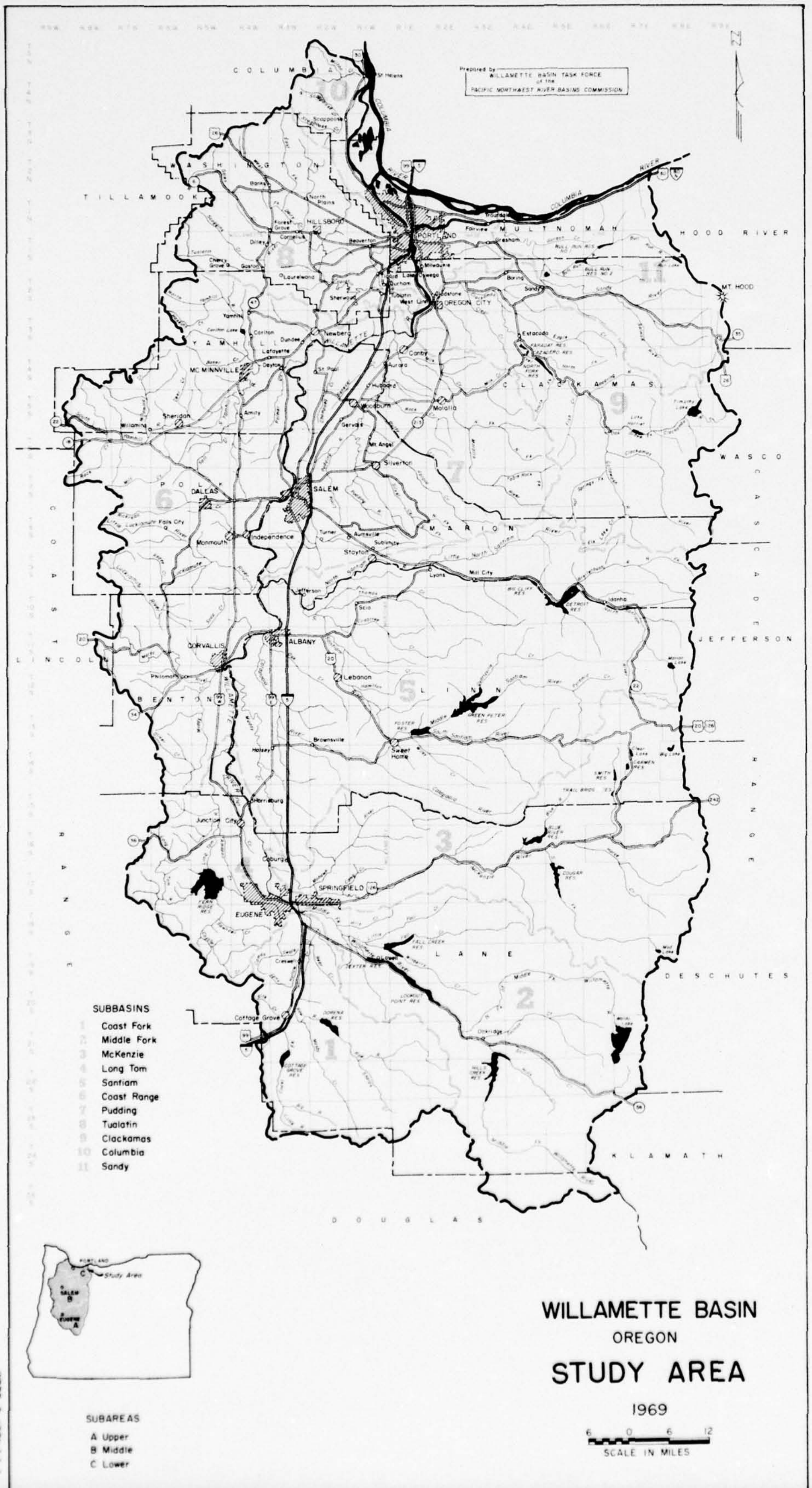
The Willamette Valley floor, about 30 miles wide, is approximately 3,500 square miles in extent and lies below an elevation of 500 feet. It is nearly level in many places, gently rolling in others, and broken by several groups of hills and scattered buttes.

Willamette River forms at the confluence of its Coast and Middle Forks near Springfield. It has a total length of approximately 187 miles, and in its upper 133 miles flows northward in a braided, meandering channel. Through most of the remaining 54 miles, it flows between higher and more well defined banks unhindered by falls or rapids, except for Willamette Falls at Oregon City. The stretch below the falls is subject to ocean tidal effects which are transmitted through Columbia River.

Most of the major tributaries of Willamette River rise in the Cascade Range at elevations of 6,000 feet or higher and enter the main stream from the east. Coast Fork Willamette River rises in the Calapooya Mountains, and numerous smaller tributaries rising in the Coast Range enter the main stream from the west.

In this study, the basin is divided into three major sections, referred to as the Upper, Middle, and Lower Subareas (see map opposite). The Upper Subarea is bounded on the south by the Calapooya Mountains and on the north by the divide between the McKenzie River drainage and the Calapooia and Santiam drainages east of the valley floor and by the Long Tom-Marys River divide west of it. The Middle Subarea includes all lands which drain into Willamette River between the mouth of Long Tom River and Fish Eddy, a point three miles below the mouth of Molalla River. The Lower Subarea includes all lands which drain either into Willamette River from Fish Eddy to its mouth or directly into Columbia River between Bonneville and St. Helens; Sandy River is the only major basin stream which does not drain directly into the Willamette.

For detailed study, the three subareas are further divided into 11 subbasins as shown on the map.



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(Some titles abridged)

INTRODUCTION

INTRODUCTION

PURPOSE AND SCOPE

Willamette Basin is a major contributor to the economic well-being of the Pacific Northwest. Its agricultural and forest lands are the basis for products shipped to the nation and the world. Its people, and their industries, provide a market for products and raw materials from national and world-wide sources.

As development in the basin continues, flood damages become greater and economically more devastating. The purposes of this appendix are to outline past and present flood problems in the basin, determine the present and future needs for flood damage reduction measures, and outline available flood damage reduction alternatives which should be considered in plan formulation. The scope of coverage includes flood characteristics, flood damages, enhancement of land values, existing projects, and damages prevented; and structural and management alternatives for prevention of flood damages.

Photo I-1 The largest economic and population centers in the basin are located along Willamette River. (OSHD Photo)

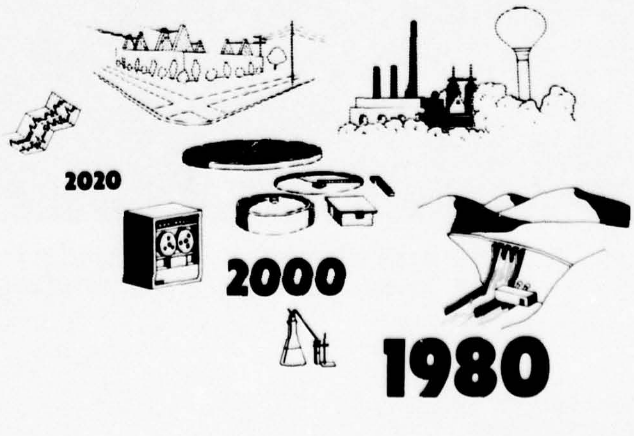
RELATIONSHIP TO OTHER PARTS OF REPORT

This appendix, in common with the other functional appendices, relies upon the supporting data contained in Appendices A - Study Area, B - Hydrology, and C - Economic Base, which define the lands and institutions, waters, and the economy of Willamette Basin. Appendix C further relates the basin's economy to the region and the nation.

In addition, there has been an interchange of pertinent information with other functional appendices. A close relationship exists between this appendix and Appendix G - Land Measures and Watershed Protection. The degree of attainment of flood control objectives is discussed in Appendix M - Plan Formulation. The data contained in this appendix are also the basis for the flood control presentation in the main report.

G - LAND MEASURES AND WATERSHED PROTECTION

M - PLAN FORMULATION



SUPPORTING APPENDICES

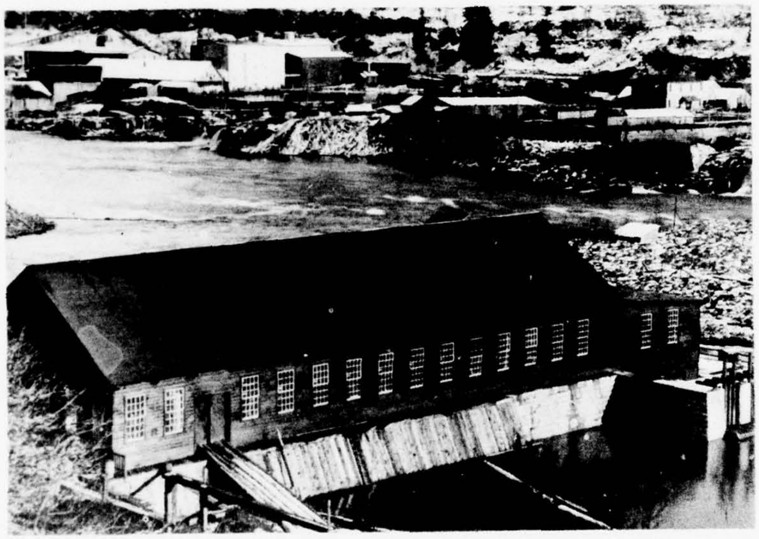
A - STUDY AREA

B - HYDROLOGY

C - ECONOMIC BASE

H I S T O R Y

Floods have plagued Willamette Valley residents from the time of the earliest historical records. Floods of varying magnitude occur each rainy season, generally during the period November through March, although there have been floods as early as October and as late as May. The greatest known floods occurred before streamflow records were maintained; consequently, very little information is available concerning the discharges. Early records of the Northwest Fur Company, which operated near Newberg, indicate that a major flood occurred on Willamette River in 1813. Historical documents also refer to large floods occurring in 1843, 1844, 1852, and 1861.



BEFORE

DURING

Photo I-2 At Oregon City the floodwaters rose until the falls were hardly distinguishable. (1890 photo by Pier Artist, Oregon Historical Society).

Flood flows (discharges exceeding bankfull stages) occur on Willamette River nearly every year, and two or more times in unusually wet years. The frequency of bank overflow is indicated by discharge records at Albany where, in the 73-year period 1893 through 1965, bankfull stage has been exceeded by 126 floods, 15 of which have exceeded bankfull by 10 feet or more. An average of slightly less than two floods per year occurred at Salem in the period 1941-64. Major floods, those where significant damages occurred, are listed from available historical data in order of magnitude at Salem in Table I-1.

Table I-1

Major floods at Salem

Flood	Peak Flow (Natural) (cubic feet per second)
December 1861	500,000
December 1964	472,000*
February 1890	448,000
January 1881	428,000
January 1923	348,000
January 1901	329,000
February 1907	325,000
November 1909	315,000
February 1961	304,000*
December 1955	304,000*
January 1943	301,000*
January 1953	290,000*
January 1965	283,400*
January 1903	283,000
December 1945	262,000*

* *Computed values; peak flows subsequent to 1941 were regulated by Corps of Engineers reservoir projects in operation in those years. See Figure I-1 for information on storage development.*

Willamette River flood profiles during selected major floods are shown in Figure I-1.

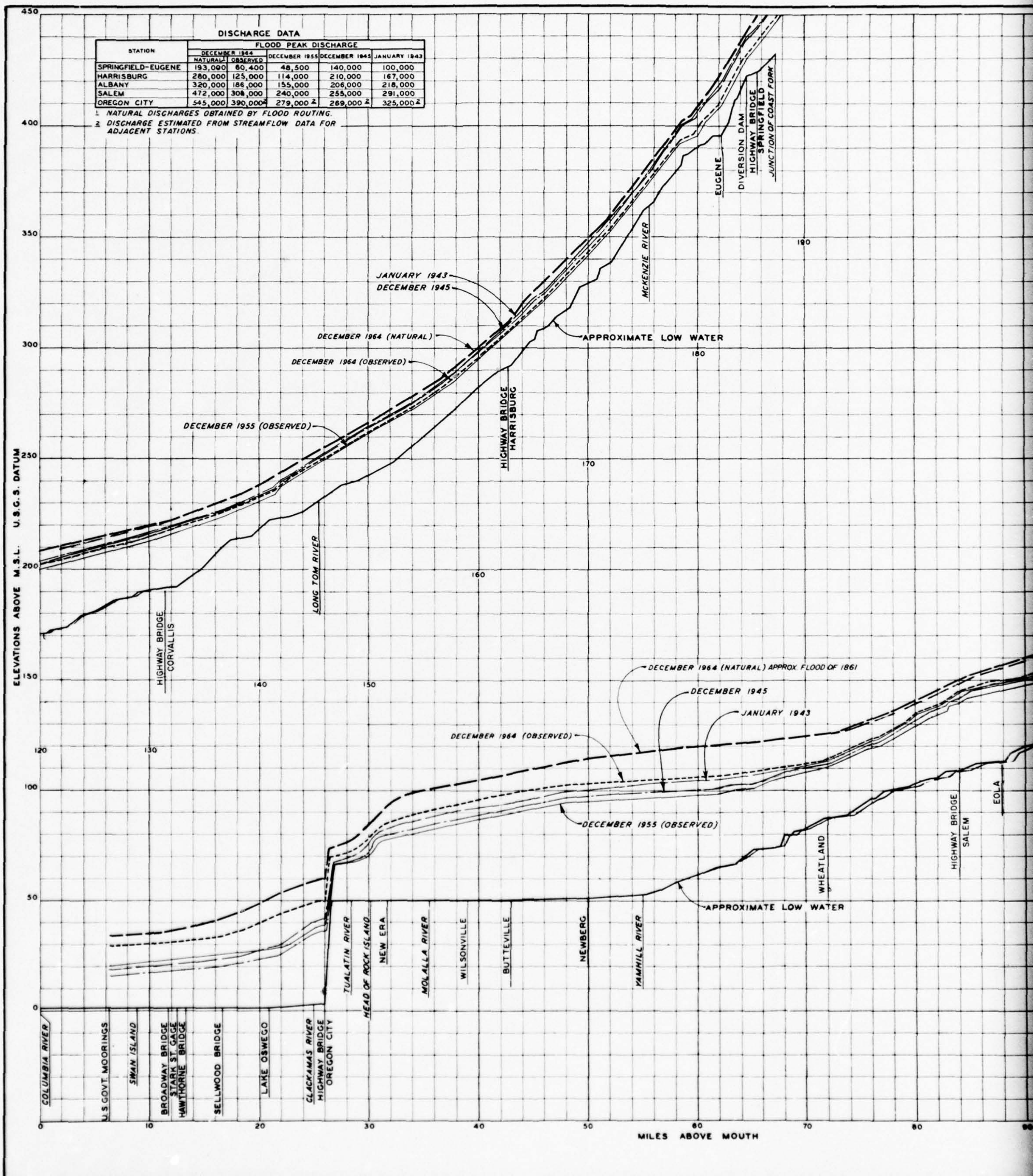
The largest flood of record at Salem occurred in 1861, when Willamette River rose to a peak stage of 47.0 feet, with an estimated discharge of 500,000 second-feet. The second largest flood at Salem, (December 1964) was reduced from what would have been a stage of 45.3 feet (472,000 cfs) to 37.8 feet (309,000 cfs) by reservoir regulation. Other recent major floods in the basin occurred in December 1955 and February 1961. The unregulated discharge at Salem for each of those floods is calculated at 304,000 second-feet, while observed flows were about 240,000 second-feet, a reduction of 64,000 cfs or a stage reduction of about 4 feet.

Although the 1861 flood was the largest at all points along Willamette River upstream from Willamette Falls, the order of magnitude for other floods at points in the upper and lower valley varied considerably. It is believed that this was caused by variations in storm paths, distribution of rainfall, and runoff characteristics of the tributary watersheds. In general, however, conditions which cause a major flood at Eugene will result in a major flood at Salem and other downstream points. Flooding at Portland is often influenced more by backwater from Columbia River than by Willamette River flows. The flood of June 1894 was caused by Columbia River.

The major flood of December 1964 resulted from intense rainfall during a period of comparatively high temperature, following an extended period when the snow at higher elevations had reached near-record depths for that time of year. Those conditions, coupled with a frozen ground surface, produced runoff that was far in excess of normal. The major floods of 1861 and 1890 undoubtedly were produced by similar conditions.

In the December 1964 flood, more than 320,000 acres of land were flooded in Willamette Basin. Floods on tributaries are characteristically of shorter duration than those along the Willamette. Although flood waters generally recede from most of the land within a very few days, in some areas ponding continues for extended periods of time.

Photo I-3 In December 1964 many homes were isolated by floodwaters. Clackamas River had already receded considerably when this photograph was taken. (USCE Photo)

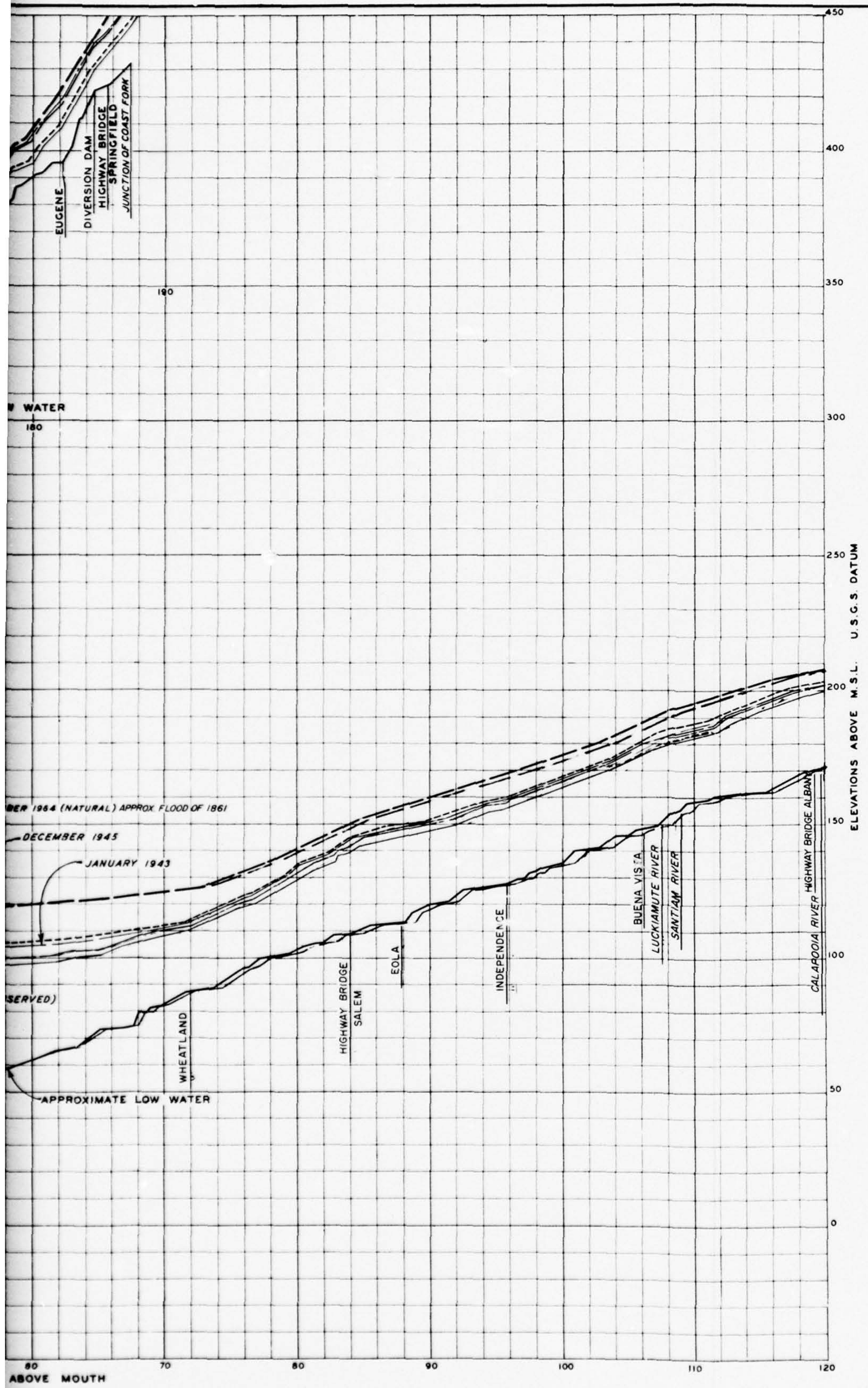


DISCHARGE DATA

STATION	FLOOD PEAK DISCHARGE				
	DECEMBER 1964		DECEMBER 1955	DECEMBER 1945	JANUARY 1943
	NATURAL[1]	OBSERVED			
SPRINGFIELD-EUGENE	193,000	60,400	48,500	140,000	100,000
HARRISBURG	280,000	125,000	114,000	210,000	167,000
ALBANY	320,000	186,000	155,000	206,000	218,000
SALEM	472,000	308,000	240,000	255,000	291,000
OREGON CITY	545,000	390,000[2]	279,000[2]	269,000[2]	325,000[2]

1 NATURAL DISCHARGES OBTAINED BY FLOOD ROUTING.

2 DISCHARGE ESTIMATED FROM STREAMFLOW DATA FOR ADJACENT STATIONS.



WILLAMETTE RIVER BASIN RESERVOIRS		
RESERVOIR	IN-SERVICE DATES FOR FLOOD CONTROL	
FERN RIDGE	NOVEMBER	1941
COTTAGE GROVE	OCTOBER	1942
DORENA	OCTOBER	1949
DETROIT	NOVEMBER	1953
LOOKOUT POINT	NOVEMBER	1953
HILLS CREEK	DECEMBER	1961
COUGAR	NOVEMBER	1963
FALL CREEK	OCTOBER	1965
GREEN PETER	JUNE	1967
FOSTER	DECEMBER	1967

Note: For storage in effect at time of flood occurrence see Table II-6

LEGEND

- DEC. 1942 - JAN. 1943 FLOOD PROFILE (OBSERVED)
- DECEMBER 1945 FLOOD PROFILE (OBSERVED)
- DECEMBER 1955 FLOOD PROFILE (OBSERVED)
- DECEMBER 1964 FLOOD PROFILE (NATURAL)
- DECEMBER 1964 FLOOD PROFILE (OBSERVED)

From Corps of Engineers Drawing PD-26-3/14, Plate 15

FIGURE I-1
WILLAMETTE BASIN STUDY
OREGON
RIVER FLOOD PROFILES
1968

2

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Early settlers generally "passed up" fertile flood plains in favor of open slopes of the foothills, but later developers started farming valley bottoms, where there is a flood hazard. Along the smaller tributaries, lands flood often--in some places several times each year. Floods most often occur during the winter season when crops are dormant, and actual production losses are not readily apparent. Lowered yields, weed problems, and hampered farm operations, however, take a toll as economic losses. Historically, farmers have sought to minimize their losses by raising relatively low-income crops that can tolerate flooding. Much of the land would be suitable for higher-income crops if flood threats were removed.

Although major floods have been individually more damaging and more widely remembered, the minor floods which occur once or more in almost every year probably have caused equal or greater total damages historically. Minor floods still cause a significant portion of the total damages on uncontrolled tributaries.

PORTLAND FLOODS

June 1894

Third St.

(USCE Photo)

June 1894

Third & Morrison Sts.

(Davis Photo, USCE)

June 1894

First & Stark Sts.

(USCE Photo)

Feb. 1890

First & Taylor Sts.

(Davis Photo, USCE)

PRESENT STATUS

PRESENT STATUS

Under the authority of various Flood Control Acts starting in 1936, many water resource development projects have been constructed to provide flood regulation. Although much progress has been made by the Corps of Engineers, the Soil Conservation Service, and local groups in the past 30 years toward alleviating flood damages in Willamette Basin, development in the flood plain has increased, thus expanding the potential for future flood damages. This became clear during the flood of December 1964. Storage reservoirs and other improvements now control floods on many of the larger tributaries of Willamette River, but floodwaters of several large tributaries and most small tributaries remain uncontrolled.

Photo II-1 An Oregon City shopping center had heavy losses during the flood of December 1964. Development in the floodplain continues to increase. (USCE Photo)

FLOOD PROBLEMS

Flood problems in Willamette Basin result from both natural factors and human management of the land. There is historical evidence that the Indian population, through periodic burning of certain hunting areas, increased rates of flood runoff. Modern man has on occasion, through his activities, also increased runoff rates, thus contributing to the flood problem.

FLOOD CHARACTERISTICS

Willamette Basin floods generally result from rainfall augmented by snowmelt. When melting snows combine with heavy precipitation, as in December 1964 (Fig. II-1), a larger-than-normal runoff occurs. During the late spring or early summer, melting snows in the Cascade Range may cause minor freshets on the eastside tributaries and Willamette River; however, floods from this cause are normally small. Below the falls at Oregon City, backwater from the annual Columbia River freshet causes high stages on Willamette River during the months of May, June, and July. The highest stages of record in Portland Harbor were from this cause.

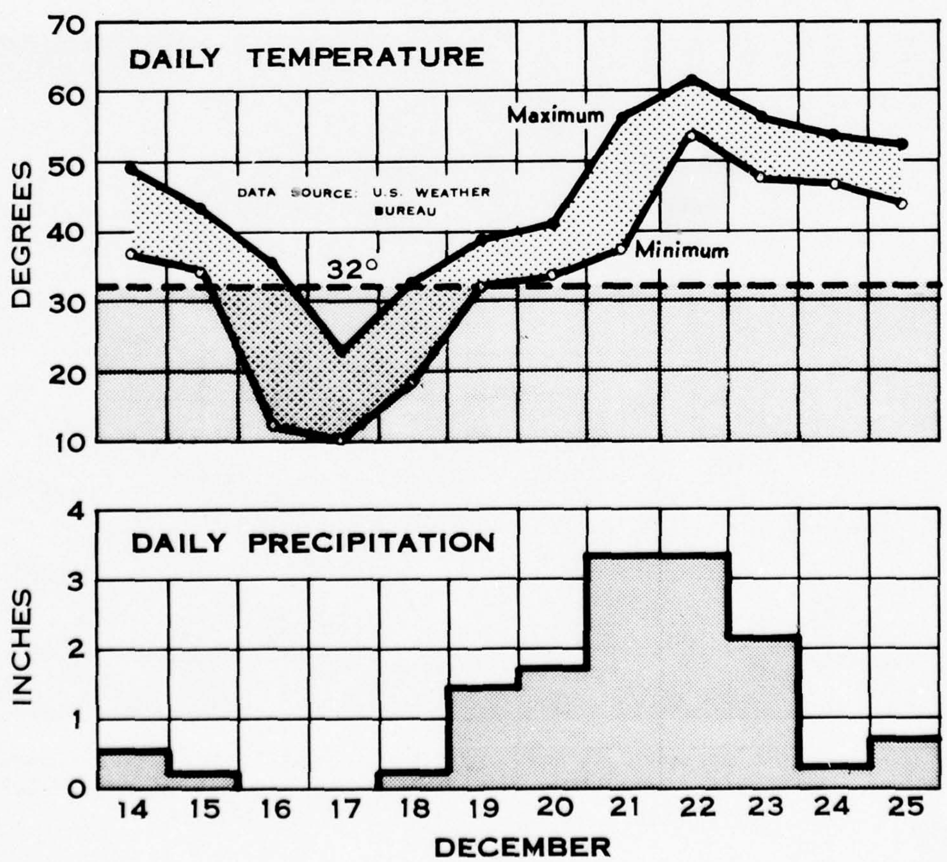


Figure II-1 Temperature & Precipitation, Eugene, Oregon, Dec.1964

Floods on the tributaries are characteristically of short duration. Usually the water rises rapidly, remains at peak stage for a few hours and subsides rapidly, returning to normal in a few days. Floods on the main stream recede much more slowly and the inundation may last several days. With the exception of saturation of topsoil, ground water has no significant relationship to floods because it reacts much too slowly to be involved in floods.

Storms

Storms in Willamette Basin are of Pacific origin and may be broadly classified into two types. One type is comprised of a series of north-south oriented fronts moving inland at intervals of 6 to 24 hours. Precipitation is more intense at the time of frontal passage, but may occur in various intensities throughout the storm as a result of orographic lifting of the air over topographic barriers. The other type of storm is characterized by an east-west oriented, quasi-stationary front associated with a strong westerly flow of moist air. Precipitation is generally of high intensity in the region of the front. Orographic lifting supplements the frontal precipitation throughout the region of westerly flow.

Duration of major Willamette storms varies from less than a day to more than 10 days; most storms are of 2 to 4 days' duration. Precipitation amounts vary from a few inches to more than 15 inches. Convective storms occur throughout the year, the most intense ones during the late spring. One-hour precipitation often exceeds 1 inch. Areal extent is comparatively small, and the flood-producing potential is relatively minor except locally. Thunder and hail are often associated with these storms.

Runoff

There are more than 100 recording stream gages in operation in the basin, and a large number of crest-stage gages and temporary staff gages. At most Willamette Basin stations, stream-gaging records have been collected for less than 30 years. The Albany station on Willamette River has the longest continuous record, since 1894. The long-term annual runoff of Willamette River at Albany showed an upward trend from 1896 to 1904, downward from 1905 to 1945, and upward again from 1946 to 1965.

Approximately 70 percent of the annual runoff occurs during a 6-month period, November through April. During the rainy season, streamflows fluctuate whenever there is significant precipitation. The greater the intensity of the storm, the greater the fluctuation, particularly when the ground is saturated from a prior storm.

In general, the tributaries heading in the Cascade Range have a greater annual runoff and flood-producing potential per square mile than tributaries heading in the Coast Range.

Stream Velocity

Stream velocities vary from more than 20 feet per second in the headwaters during flood periods to less than 2 feet per second in the lower reaches of Willamette River during low-flow periods. Although bank erosion occurs during all high-water periods, the greatest losses are experienced at bankfull and higher stages. In its lower 26 miles downstream from Willamette Falls, the stage and velocity of Willamette River at lower stages are affected by tidal action and occasionally by backwater from Columbia River.

Duration and Magnitude

The magnitude of any individual flood is a function of the precipitation intensity, duration of the storm, snow cover, temperature, and degree of saturation of the topsoil. Streams fluctuate widely during the rainy season, and several periods of high water are normally experienced each year. Headwater streams are seldom above flood stage more than 5 days, and valley streams more than 10 days. Longer flood periods have been experienced, but those occasions were the result of a series of quasistationary fronts that developed along the Oregon Coast. Flood peak runoff from the more mountainous areas occasionally exceeds 100 cfs per square mile. In December 1964, peak discharges recorded on streams heading in the Cascade Range exceeded 200 cfs per square mile.

On many streams in the basin, a flood as great as that of December 1964 could be expected to recur only once in about 100 years on the average. A flood of this magnitude, which has a one-percent chance of occurring in any year, is termed a 100-year flood. A flood magnitude with a two-percent chance of occurring in any year is a 50-year flood, and so forth. The larger the flood, the smaller its probability of occurrence in any year.

Optimum Flood-Producing Conditions

Intense precipitation, frozen ground, heavy snow cover, high temperature, and saturated soil are conducive to maximum runoff. Snowmelt added to the precipitation produces unusually large water excesses over a relatively short time. These conditions have contributed to the major floods on Willamette River. Ice rarely forms on the Willamette or its tributaries, and flooding caused by ice jams is not a problem.

Occasionally, a series of significant precipitation-producing storms, augmented by snowmelt, result in a broad-crested flood. Normally, the flood crest from the upstream watershed arrives at Eugene 18 hours after the intense portion of a storm. The travel time of the flood wave down Willamette River is influenced by the direction of the storm path and by the location of the storm center. On the average, a flood wave travels from Eugene to Albany in 30 hours, from Albany to Salem in 12 hours, and from Salem to Portland in about 35 hours.

Major floods are sometimes the result of storms whose centers travel from the southwest. In such cases, the storm travels in the general direction of the flood wave in Willamette River, and peak discharges are accentuated progressively downstream. Both the 1861 and 1890 floods resulted from this type of storm.

Photo II-2 The flood of 1890 put Salem's main section under water. (OAC Photo)

FLOOD AREAS

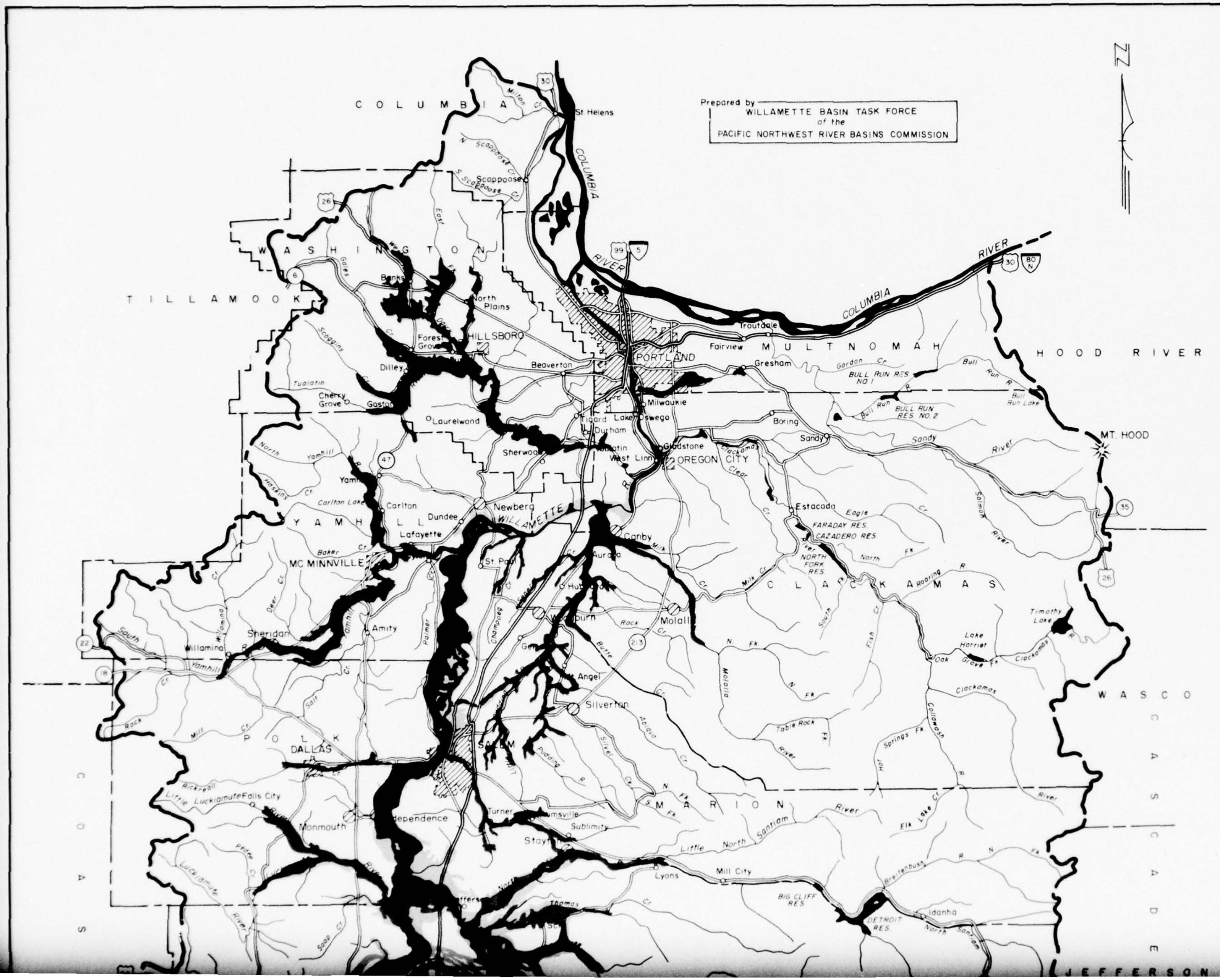
The area subject to flooding extends along the Willamette and its principal tributaries, over a total stream distance of about 1,100 miles. During major floods, overflows from Willamette River and major tributaries combine with overflow from lesser streams, forming a continuous flood plain including most of the tributary flood plains. During minor and moderate floods, the flood plains of individual streams are separate and distinct from the Willamette flood plain.

Minor, frequently recurring floods inundate at least 100,000 acres in the basin. The annual average area flooded is about 177,000 acres (Table II-1), of which some 37 percent lie along the smaller, generally uncontrolled tributaries.

Table II-I
Average annual flood plain

Subbasin	Area Inundated (Acres)
Coast Fork	3,700
Middle Fork	500
McKenzie	1,100
Long Tom	11,800
Santiam	50,500
Coast Range	51,600
Pudding	28,300
Tualatin	15,500
Clackamas	800
Columbia	10,200
Sandy	2,600
Total	176,600

A much larger area is inundated by major floods. The width of the flooded area in 1861 ranged from a few hundred feet in the upper reaches of tributary streams to a maximum of 11 miles on the valley floor (Map II-1). The floods of 1861 and 1964 were of similar magnitude; the areas inundated, however, were 513,000 and 211,000 acres of agricultural land, respectively, along the Willamette and major tributaries only. The difference was due largely to the regulation provided in 1964 by seven storage reservoirs and partly to urban development which reduced the amount of agricultural land on the flood plain in 1964. The agricultural acreage inundated in 1861 and 1964 along the Willamette and major tributaries is shown by reaches in Table II-2. An additional 108,000 acres along the minor tributaries were flooded in 1964.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CLACKAMAS
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Tigard
Durham
Tualatin
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MT. HOOD
BULL RUN RES NO 1
BULL RUN RES. NO 2
Bull Run Lake
FARADAY RES
CAZADERO RES
NORTH FORK RES
Timothy Lake
Lake Harriet
BIG CLIFF RES
DETROIT RES
Sandy River
Salmon River
Clackamas
Collowash
Molalla
Table Rock Fk
Pudding R
Little North Santiam
North Santiam
Breitenbush
Luckiamute River
Little Luckiamute
Rickreall
Yamhill
Tualatin
Scoggins
Gales
Milton Cr
Scappoose Cr
Gordon Cr
Eagle Cr
Clear Cr
Milk Cr
Abiqua Cr
Butte Cr
Rock Cr
Champoeg
Palmer
Salt
Baker Cr
Deer Cr
Haskins Cr
Carlton Lake
Oak Grove Fk
Elk Lake Cr
Hot Springs Fk
Thomas Cr
Soap Cr
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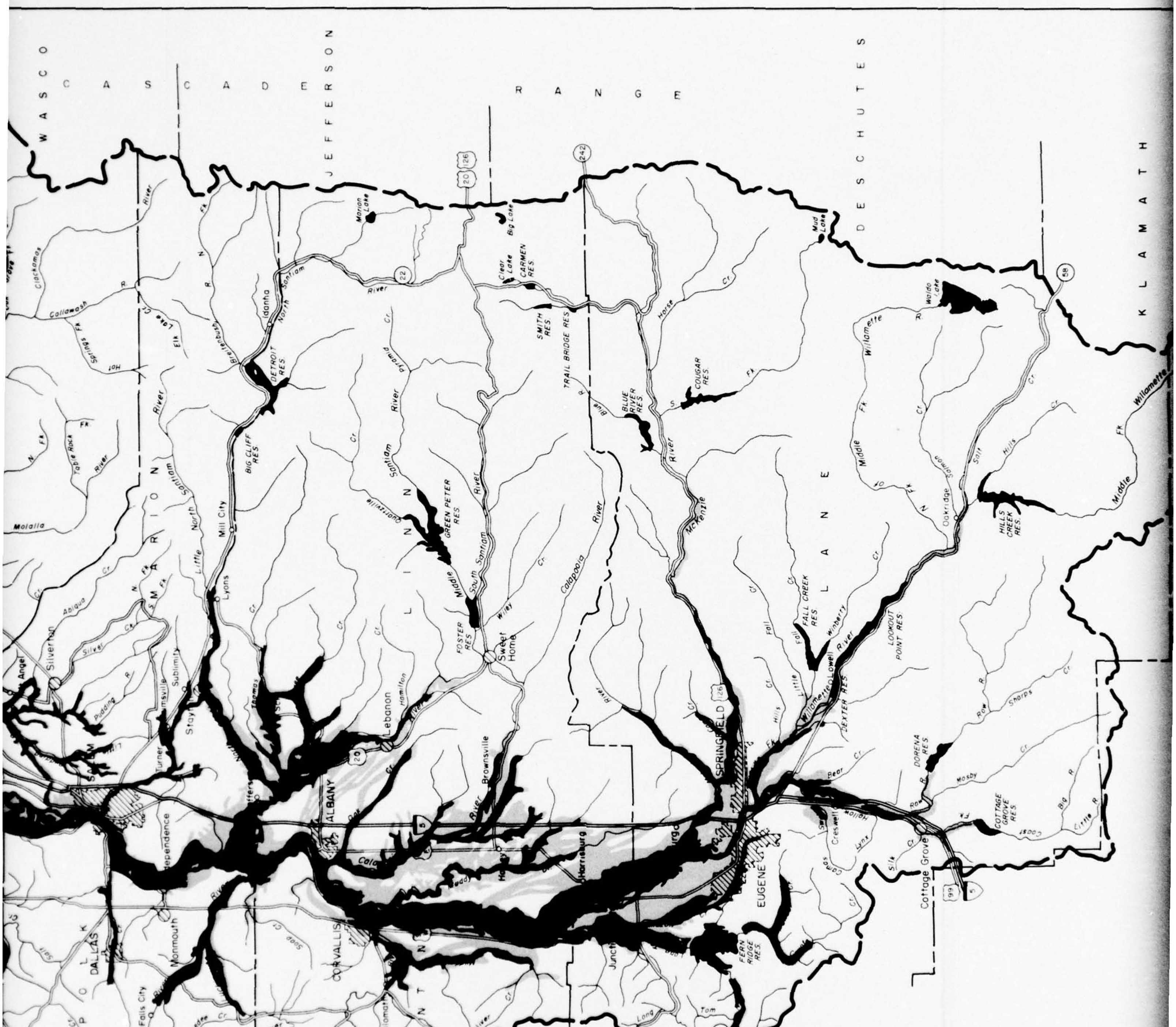
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MARION
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C O A S T
R A N G E
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Silverton
Sublimity
Turner
Stayton
Lyons
Mill City
Idanha
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BIG CLIFF RES.
Marion Lake
Big Lake
Clear Lake
CARMEN RES.
SMITH RES.
TRAIL BRIDGE RES.
BLUE RIVER RES.
COUGAR RES.
GREEN PETER RES.
FOSTER RES.
Sweet Home
Lebanon
ALBANY
Brownsville
Harrisburg
CORVALLIS
Philomath
Monmouth
DALLAS
Falls City
Independence
SPRINGFIELD
EUGENE
FERN RIDGE RES.
FALL CREEK RES.
LOOKOUT POINT RES.
DEXTER RES.
Lowell
Oakridge
HILLS CREEK RES.
Waldo Lake
Mud Lake
DORENA RES.
COTTAGE GROVE RES.
Cottage Grove
Creswell
McKenzie
Calapooia River
South Santiam
Middle
North Santiam
Willamette
Luckiamute River
Long Tom
Mosby Cr.
Row R.
Sharps Cr.
Salt Cr.
Hills Cr.
Fall Cr.
Winberry
Wiley Cr.
Quartzville
Pyramid Cr.
Horse Cr.
Hamilton
Thomas
Pudding R.
Abiqua Cr.
Silver Cr.
Table Rock Fk.
Hot Springs Fk.
Collawash R.
Clackamos
Breitenbush
Elk Lake Cr.
Little North Santiam
Pedee Cr.
Oliver Cr.
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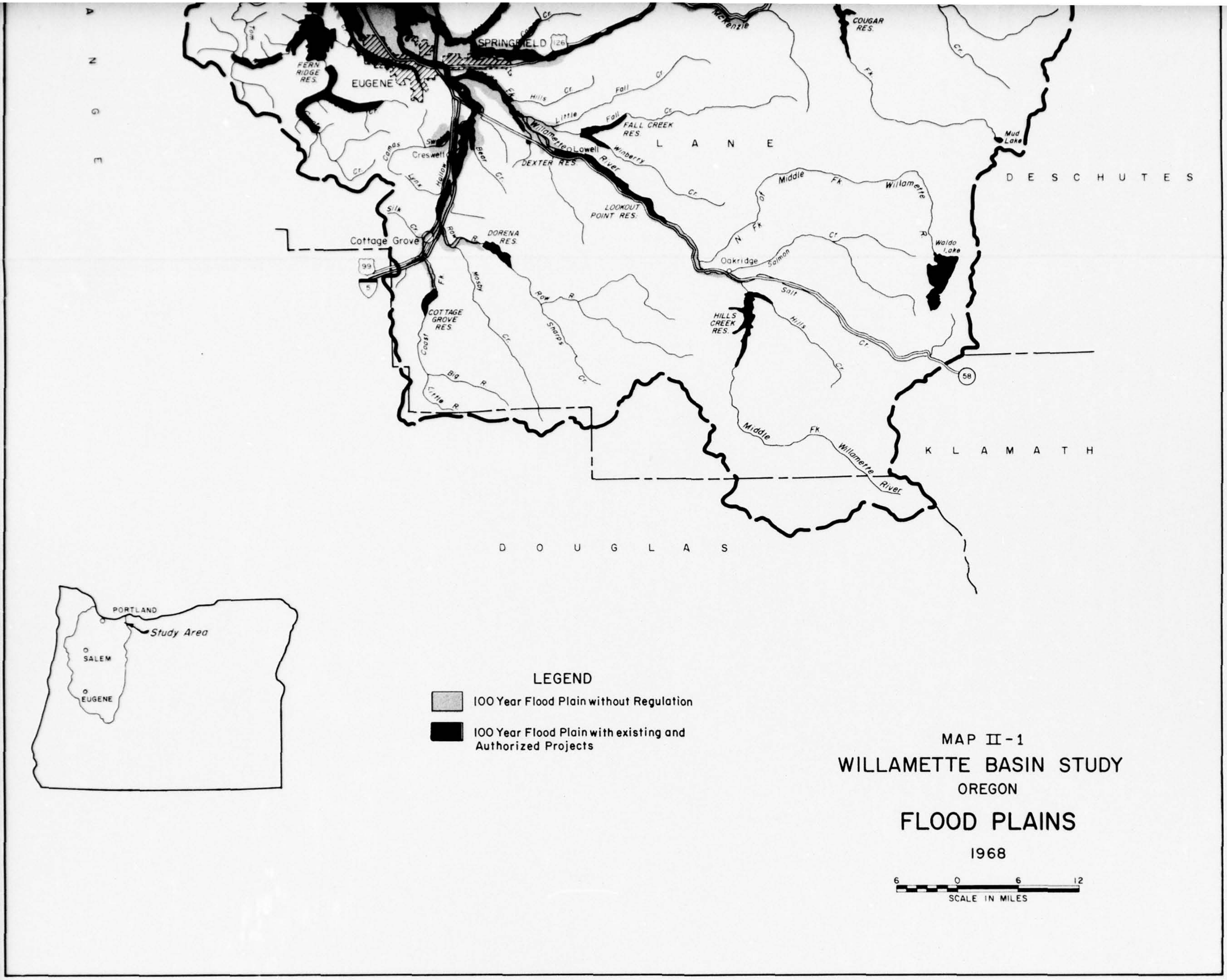

MAP II-1
WILLAMETTE BASIN STUDY
OREGON
FLOOD PLAINS
1968

1

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3

Table II-2

Agricultural land inundated in 1861 and 1964 floods
Willamette River and major tributaries

Reach	Areas Inundated (Acres) 1861	1964 *
Upstream from Eugene	62,000	11,200
Eugene to Corvallis	172,900	32,100
Corvallis to Salem	155,200	113,100
Salem to Oregon City	116,200	52,500
Oregon City to mouth	6,700	2,600
Totals	513,000	211,500

* *The 1964 flood was regulated by seven storage reservoirs; see Figure I-1 for those reservoirs then in operation.*

Protection of the steep, forested watersheds from disturbances caused by road construction and logging is a major problem. Debris, both from logging and natural causes, frequently jams against bridges and other structures in stream channels, causing major increases in flood damage. Debris also accumulates in reservoirs and rivers, interfering with navigation and damaging recreational and scenic values. About 70 percent of the basin is forested.

Photo II- 3 This was fertile farmland until floodwaters eroded the topsoil leaving only sand, gravel, & debris. (USCE Photo)

One important facet of lesser floods is their effect on agricultural irrigation. The irrigation potential of land flooded once in every five years is significantly impaired because of added costs required to maintain these lands in a condition suitable for irrigation. The growing of perennial crops or winter cover crops (with annuals) is necessary to minimize erosion.

In Willamette Basin, a five-year frequency flood would inundate about 39,000 acres of irrigated land and an additional 123,000 acres of potentially irrigable land. The acreage that would be inundated by a five-year flood under reservoir control conditions as of November 1968, is shown in Table II-3. For further information on flooding of irrigable lands, see Appendix F - Irrigation.

Table II-3
Irrigable land subject to 5-year flood
(Acres)

Subbasin	Irrigated	Potentially Irrigable
1 - Coast Fork	990	4,380
2 - Middle Fork	70	830
3 - McKenzie	2,210	3,030
4 - Long Tom	4,010	16,960
5 - Santiam	9,720	24,300
6 - Coast Range	7,730	33,930
7 - Pudding	7,340	20,870
8 - Tualatin	6,030	17,410
9 - Clackamas	750	1,480
10 - Columbia	80	130
11 - Sandy	0	20
Willamette Basin	38,930	123,340

FLOOD DAMAGES

Of the known Willamette Basin floods, the 1861 flood was both the greatest in magnitude and the first for which any meaningful data are available. Other notable basinwide floods occurred in 1890, 1923, 1943, 1945, 1955, 1961, and December 1964. Had the 1964 flood not been regulated by upstream storage, it would have been comparable to the 1861 flood. Damages sustained during the five most recent major floods are shown in Table II-4.

To indicate the nature of damages from a major flood, a description of the December 1964 flood follows.

Table II-4

Damages from recent major floods

Item	1943		1945		1955		1961		1964	
	$1,000 Damage	% of Total	$1,000 Damage	% of Total	$1,000 Damage	% of Total	$1,000 Damage	% of Total	$1,000 Damage	% of Total
Agriculture	13,830	40.7	15,450	62.7	9,470	62.2	3,890	81.5	16,420	23.3
Industrial	9,040	26.6	3,720	15.1	1,230	8.1	120	2.6	10,780	15.2
Commercial	1,520	4.5	2,120	8.6	260	1.7	160	3.2	7,400	10.5
Util. & Trans.	2,930	8.6	1,410	5.7	880	5.8	180	3.7	17,720	25.0
Residential	810	2.4	1,180	4.8	580	3.8	40	0.9	9,200	13.0
Other	5,840	17.2	760	3.1	2,790	18.4	390	8.1	9,240	13.0
Total (rounded)	34,000		24,600		15,200		4,800		70,700	
Price levels (year)	1943		1946		1956		1962		1965	

Note: MULTIPLE-PURPOSE STORAGE RESERVOIRS OPERATING DURING THE VARIOUS FLOODS:

Year of Flood	Reservoirs in Operation
1943 and 1945	Fern Ridge, Cottage Grove
1955 and 1961	Fern Ridge, Cottage Grove, Dorena, Detroit, Lookout Point
1964	Fern Ridge, Cottage Grove, Dorena, Detroit, Lookout Point, Hills Creek, Cougar

The 1964 flood was devastating in character and extent. Surface erosion was extensive, cutting gullies 15 to 20 feet deep the entire length of many farms. Much of the eroded topsoil was carried downstream and lost. Deposition of coarser materials caused severe damages; some fields were completely buried under 1 to 4 feet of sand and gravel. One of the most significant aspects of this flood was the amount of debris load and the many massive jams and drifts left in its wake. The battering and erosive action of the large debris load greatly increased the destructiveness of the flood. This damaged most of the bank protective works, some severely, and caused numerous channel changes. Many recreation sites and facilities were damaged or destroyed. The debris came from logging operations, from accumulated windfalls in the headwaters, from debris standing in old river sloughs, from streambank brush and trees uprooted during the flood, and from structures destroyed by the flood. Many tributary streams were left with unstable, debris-clogged channels with restricted capacity. Channel conditions were also worsened by numerous landslides which occurred a month later during the flood of January 1965, a considerable flood in its own right. Future floods could dislodge part or all of this debris accumulation and cause additional damage.

The extent of loss in land fertility, weed infestation, and especially injury to orchards from siltation, erosion, or uprooting will not be fully known for many years. It will take several years and much effort before some areas will regain former productivity.

Photo II-4 An orchard after the floodwaters of the Willamette River have receded, leaving roots exposed by erosion. (USSCS Photo)

Complacency was responsible for much damage in areas where flood stages are reduced by upstream storage. Except for the flood of February 1961, flood damages since 1955 had been minor. Knowledge of additional storage projects completed and under construction had led to a general feeling of security, particularly along Willamette River. At least in part for that reason, some fields were left open during the winter without the natural protection from erosion afforded by a sod cover; more lands adjacent to streams were cleared, and houses, utility buildings, and commercial and business establishments increasingly encroached on the flood plain in recent years. All of these things increased the potential for flood damage.

Except in the Upper Subarea, which benefited greatly from regulation by storage reservoirs, major flood stages were exceeded in December 1964 at all representative stations on Willamette River. The Portland area, due partially to the backwater effect of a coincidental winter flood on the Columbia, experienced the highest winter stage in history. Unregulated tributaries generally experienced 100-year frequency floods, many having peak discharges exceeding previous recorded peaks by as much as 50 percent.

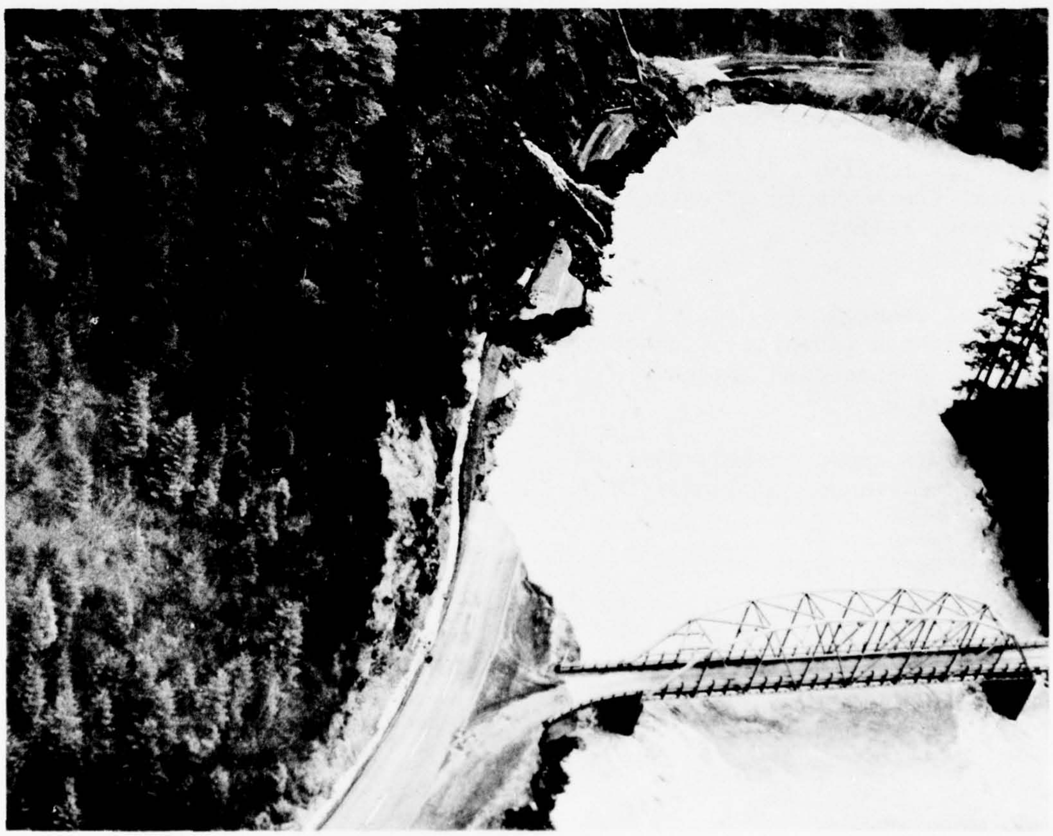


Photo II-5 Many sections of highway in the basin were destroyed by swift floodwaters in December 1964. (OSHD Photo)

A survey was made to determine total cumulative damages caused by the December 1964 and January 1965 floods. It was found that most of the damage occurred during the 1964 flood, although some landowners had difficulty in identifying the division of damage between the two occurrences. Damages resulting from those two floods were extremely severe, amounting to about $71,000,000. Without the reservoirs, damage would have been on the order of $580 million; thus, about $510 million in damages were prevented by the reservoirs. Table II-5 contains a summary of the 1964-1965 flood damages for Willamette River and tributaries.

Table II-5
Damages from the December 1964-January 1965 floods
1965 price levels

Item	Willamette River ($1,000 damage)	Tributaries ($1,000 damage)
Agricultural	$ 9,957	$ 6,464
Residential	4,039	5,166
Commercial	6,388	1,010
Industrial	10,200	570
Utilities	789	3,140
Transportation	4,286	9,501
Public facilities	753	315
Channel improvements & control structures	1,191	6,134 *
Emergency relief	477	369
Total	$38,080	$32,669
Physical damages	$28,961	$26,868
Flood fight & rehabilitation costs	2,600	2,043
Business & financial losses	6,519	3,758
Total	$38,080	$32,669

* *Includes approximately $900,000 damages at Green Peter Reservoir, which was under construction during the flood.*

Damages sustained along the Willamette River and tributaries during the 1964 flood are described in the following section, by principal reaches.

Willamette River

Eugene to Albany

Regulation by six multiple-purpose reservoirs in the tributary sub-basins (Hills Creek, Lookout Point, Cougar, Dorena, Cottage Grove, and Fern Ridge) was very effective in reducing flood stages in this reach. Despite record or near-record inflow at all reservoirs, maximum discharge at Eugene was only about 40 percent of previous historical peaks. Although bankfull stage was exceeded by 4 feet, the stage reduction was almost 15 feet. Prior to reservoir construction, the Eugene area received a major share of Willamette Basin flood damages--in this flood, reservoir operation reduced the share to one percent of basin totals.

Extensive flooding occurred immediately downstream from Eugene; Goodpasture Island and the flood plain east of Santa Clara were nearly completely inundated, probably influenced by backwater from McKenzie River. The Eugene water intake was damaged by the McKenzie. This area is largely agricultural, but the number of suburban homesites is increasing.

Between Eugene and Corvallis, improvements generally have been located on higher ground, and as a result, nearly four-fifths of total damages in this reach were agricultural. In the Harrisburg area, Willamette River flows increased to about 60 percent of the previous record maximum, the result of unregulated side flows plus a large discharge from McKenzie River. Flooding downstream to Harrisburg was generally shallow and the flood plain was discontinuous, averaging about 2 miles in width with overflow occurring on both banks. From Harrisburg north to Corvallis, flooding occurred almost exclusively on the left (west) bank, and the area inundated widened to approximately 3 miles.

Between Corvallis and Albany, flows were approximately 70 percent of previous historical record discharges. In this reach, the flood depths were greater, because the stream gradient flattens and the flood plain narrows to about 1 to 1-1/2 miles. At Corvallis, most of the flooding occurred on the agricultural lands across the river from the city. The city center of Albany also largely escaped inundation. Severe flooding occurred in the North Albany area, which was partially evacuated during the flood.

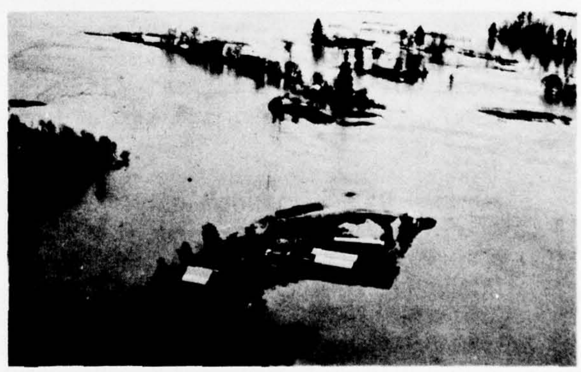
Albany to Salem

Flood depths averaged from 3 to 10 feet in American Bottom, Independence Bottom, Hayden Slough, Browns Island and Minto Island. Primary damages were from surface erosion and debris. Large acreages of berries, sugarbeets, hops and mint were completely destroyed, requiring replanting after land rehabilitation. Several individual losses were in excess of $100,000. Commercial damages, however, were minor.

1964 FLOOD - SOUTHERN BASIN

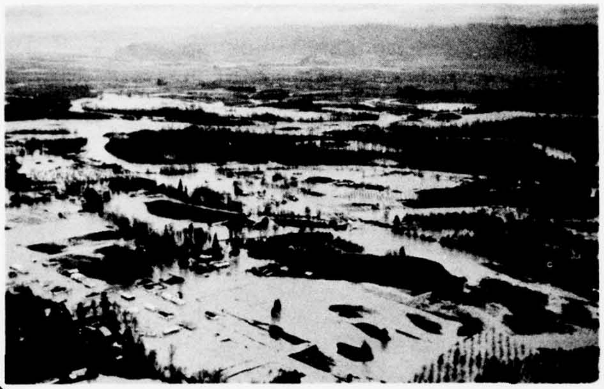
Corvallis, looking northeast across the Willamette River

Long Tom River near confluence with Willamette River

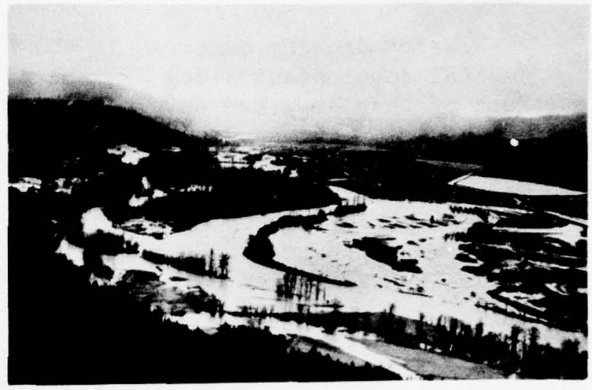


Irish Bend, typical agricultural bottom land flooding

Fern Ridge Reservoir discharging into the Long Tom River channel

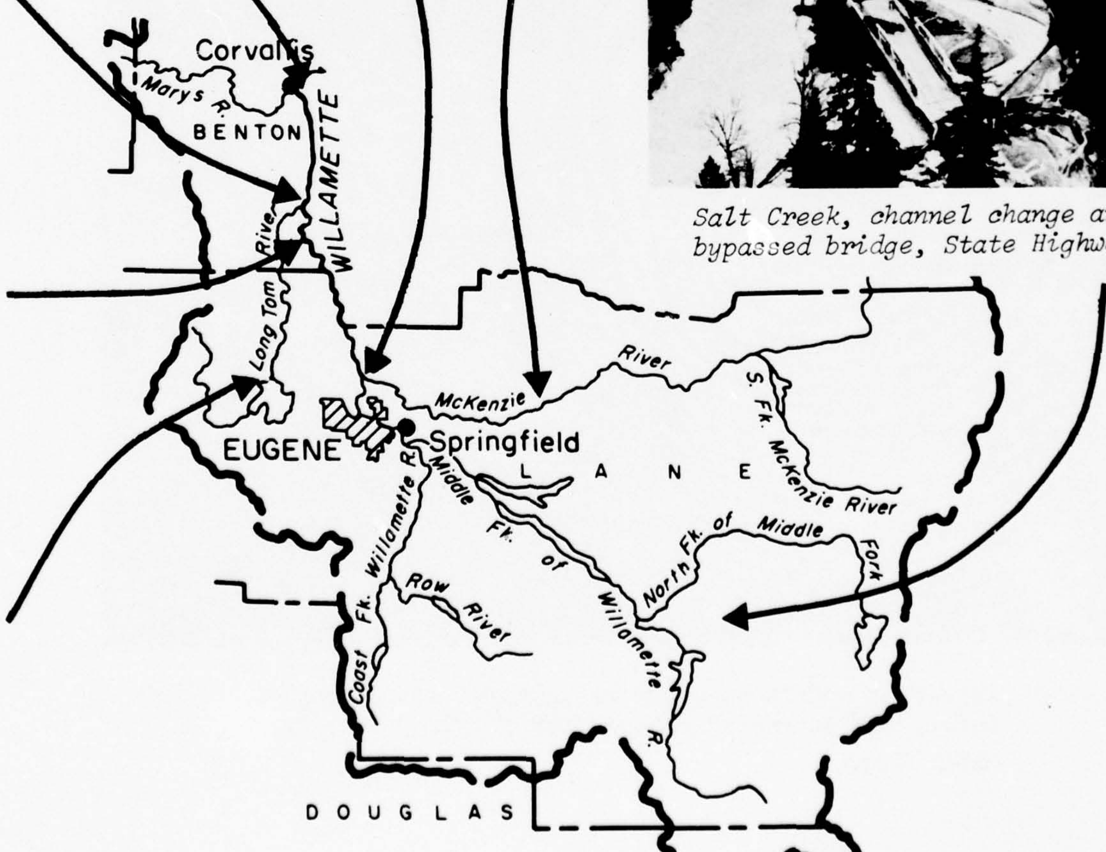


McKenzie River confluence with Willamette River



McKenzie River looking down-stream at Walterville

Salt Creek, channel change and bypassed bridge, State Highway 58



Salem Area

Major damages occurred in the Keizer area--a modern suburban residential development along Willamette River on the north edge of Salem. Much of that area had developed within the past 10 years. More than 300 houses, with an estimated average value of $26,000 for house and lot, were affected, with flooding depths up to 9 feet. Three houses were washed off the foundations and completely destroyed. Average water depth in the houses was approximately 12 inches, and damages to land and improvements averaged $1,500 per home. In addition, about 50 houses in west Salem were flooded.

Extensive commercial and industrial damages occurred along both banks of the river. The recently constructed sludge ponds of the Boise Cascade Corporation's paper mills were completely destroyed. The City of Salem's sewage plant was inundated. Facilities of several marinas were washed away and moorage basins silted in. Several gravel plants in the area were severely damaged by silting and erosion. The Illahee Golf Course, Salem Golf Club, and McNary Golf Course suffered heavy damages to fairways and greens.

Photo II-6 Keizer, a modern suburban residential development north of Salem, had extensive damage from flooding in 1964. (OSHD Photo)

Photo II-7 Houses in Keizer afloat and being carried downstream by the swift floodwaters of December 1964. (USCE Photo)

Stores and hotels in downtown Salem suffered damages from sewers backed up by high river stages. Extensive damages occurred on Shelton Ditch, nearly all downstream from Winter Street. Flooding in this area was due almost entirely to Willamette backwater, as flows in Shelton Ditch had started to recede without having done serious damage before the Willamette crested. Damages consisted of extensive flooding in the Pringle Park area, inundation and evacuation of Salem Memorial Hospital, and flooding of doctors' offices, residences, and commercial establishments.

Salem to Oregon City

Between Salem and Butteville, areas flooded included all the lowlands from Salem to Wheatland Ferry, Grand Island, Horseshoe Lake, the delta of Yamhill River, the Skookum Lakes area, Coffee Island Bar area, and Champoeg Park. Damages in this reach of the river were primarily agricultural. Extensive surface erosion occurred between Salem and Wheatland Ferry. In order to restore the continuity of the farms, earth movers and scrapers were used during cleanup to level and fill gullies that were cut through fields. Livestock losses were nominal because of limited use of the flood plain for grazing, but damage to field crops and orchards was extensive.

Between Butteville and the mouth of Molalla River, numerous expensive homes were inundated and private docks destroyed. Several marinas sustained severe damages. In this reach, where the river flows within high banks, damage occurred only to those structures and lands near the river's edge.

The right bank of Willamette River is low at the mouth of Molalla River. Damages on the Molalla up to its confluence with Pudding River, about 1 mile upstream, were caused primarily by Willamette River backwater. Upstream from that point, damages were caused by Molalla and Pudding floodwaters. On the flood plain near the mouth of the Molalla, a large peach orchard was covered with silt up to 4 feet deep and pastures supporting dairy operations were badly eroded.

Downstream from the Molalla, where the Willamette enters a rocky gorge, limited flood damages occurred to only a few dwellings and waterfront businesses. At West Linn, where the flood plain widens, about 80 acres of pasture land and several residences along the river's edge were inundated and two sewage treatment plants were damaged.

At Willamette Falls, Willamette River inundated the first floors of large paper plants on both banks, damaging motors, equipment and stock, and causing prolonged shutdowns. Damages running into millions of dollars were sustained.

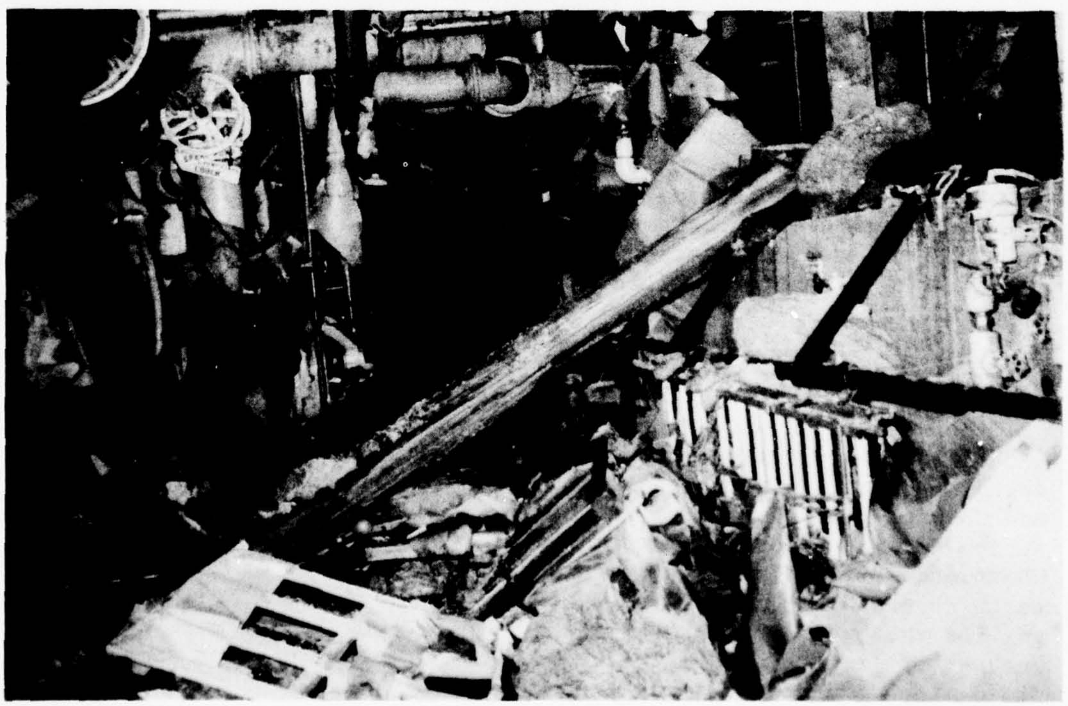


Photo II-8. The interior of a papermill at Willamette Falls, showing the aftermath of the 1964 flood. (Crown-Zellerbach Photo)

Photo II-9. During the 1964 flood, the highest winter stages in history were experienced in Portland Harbor. The lower lift span of this bridge had to be raised shortly after this photograph was taken. (USCE Photo)

<u>Oregon City to Willamette River Mouth (Includes Portland)</u>

Between Oregon City and the Sellwood Bridge, unincorporated residential areas and areas of Portland bordering Willamette River are made up of attractive homes averaging $30,000 in value spaced at about 100-foot intervals, with few unimproved land areas. Heavy damage was sustained by the structures, landscaping, recreational facilities, floats, dolphins, pilings, and boathouses. Many heretofore flood-free structures were inundated, some to depths exceeding 10 feet. Much movable property which had been thought to be above any possible flood level was severely damaged. Privately operated moorages and pleasure craft were extensively damaged by debris.

Willamette backwater submerged the Woodbury Industrial Park at Lake Oswego to a depth of 12 feet, causing extensive damage.

Along the Portland waterfront, industrial areas between the Sellwood and Hawthorne Bridges sustained the greatest losses. Damages in the lower harbor were due principally to the swift current and tremendous debris load. The large industrial complex located on Swan Island was slightly above the flood crest and was not damaged physically by the flood. Areas adjacent were inundated, but the damages were minor in relation to the value of the improvements.

1964 FLOOD - NORTHERN BASIN

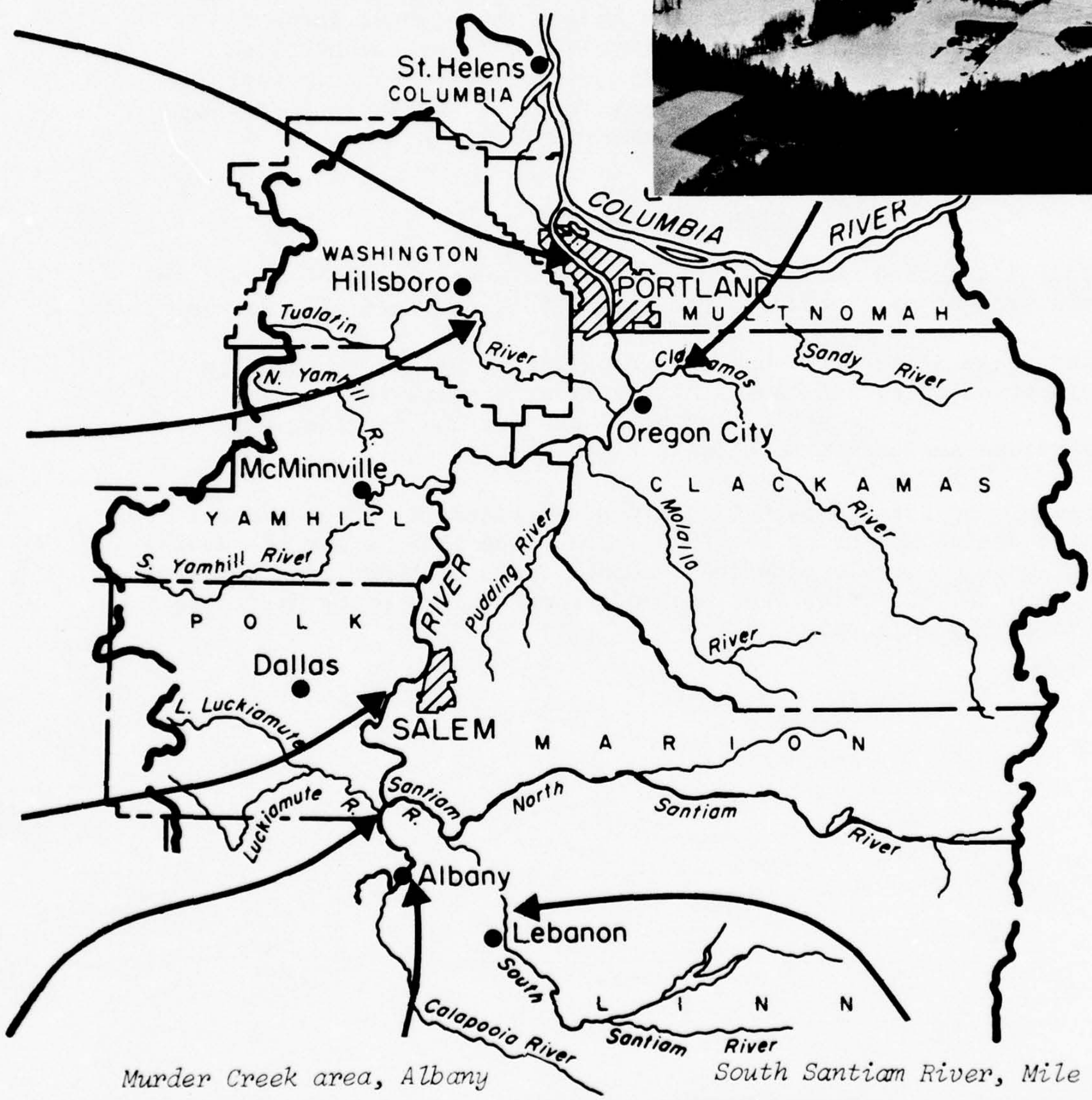
Portland, disruption of rail traffic, warehousing & business activities

Tualatin River, looking downstream from the vicinity of Hillsboro

Hayden Island, confluence of Rickreall Creek with Willamette River

Flooded agricultural land at the confluence of Luckiamute and Willamette Rivers

Farm on near bank under water,
Clackamas River, Mile 5



Murder Creek area, Albany

South Santiam River, Mile 17

Tributary Streams

Damages sustained on major and minor tributary streams were similar to those described for Willamette River; the highest damages occurred in urban, suburban, and industrial areas on uncontrolled streams. Detailed descriptions of damages sustained on tributary streams are contained in the U. S. Army Corps of Engineers Postflood Report for the December 1964 and January 1965 floods.

Intangible Damages

Loss of life and human suffering are the most elemental of all the disasters wrought by floods. During the 1964 flood, one life was lost.

Disruption of services has an intangible as well as a tangible cost. Inconveniences are caused by interrupted communication and transportation, schools are closed until repairs can be made, and other services are unavailable for a time.

Some of the basin's esthetic values, particularly environmental ones, were destroyed during the 1964 flood. One example was the devastation of once desirable campground areas. Some of these were unrestorable because the qualities that had made them attractive or desirable were damaged beyond repair.

FLOOD DAMAGE SURVEYS

Flood damage surveys by the Corps of Engineers are generally restricted to the flood plain of Willamette River and its major tributaries. Surveys of smaller tributaries are generally made by the Soil Conservation Service. The Forest Service also makes surveys of certain types of flood damage.

Corps of Engineers

The Corps of Engineers makes flood damage surveys in connection with postflood reports and for evaluation of potential projects. Input data are obtained from Federal and State agencies and local sources. Postflood reports are prepared for all major floods, and for lesser floods when special conditions warrant. These reports include flood hydrology, flood damages sustained, evaluation of stage and damage reduction by projects in operation, and estimates of damages that would have been prevented by authorized and by recommended (not yet authorized) projects. Data in such reports are useful in evaluating the need and justification for flood control projects.

Surveys for evaluation of potential projects involve the collection of data concerning lands and improvements subject to inundation, to determine probable amounts of average annual flood damage with and without projects under consideration.

Damage surveys are made as soon as possible after the flood occurs so that its effects can be best observed. For winter floods, such as occur in Willamette Basin, many types of damage cannot be accurately assessed until at least 2 or 3 months after the flood. This is especially true of farm damages such as crop losses, cost of soil rehabilitation, and property repair and renovation. Damages to other properties--industrial, commercial, residential, roads, and railroads--also are assessed. Damages are determined whenever possible by at-site interviews with affected parties.

The extent of coverage is dependent upon several factors, including the severity of flooding, the physical possibility of reducing damages by flood-damage-reduction measures, and the probable economic feasibility of such measures. Flood damage surveys have been conducted by the Corps of Engineers for five major floods: January 1943, December 1945, December 1955, February 1961, and December 1964. The scope of survey coverage was greater for the 1955 and 1964 floods than for the others. Total damages for each of the five floods surveyed are shown in Table II-4.

Soil Conservation Service

Following the 1964 flood, flood damage surveys were conducted by the Soil Conservation Service in the smaller tributary areas of the basin. Observed flood plains were delineated on aerial photographs for 33 small tributary areas, and points of damage were identified. These data were then used, along with landform studies, to develop annual and maximum flood plain acreages in order to estimate the area flooded in the remaining small tributary area; resulting data were combined with Corps of Engineers survey data.

Along the Willamette and its major tributaries, about 212,000 acres of agricultural land were flooded in December 1964. On the small tributaries, an additional 108,000 acres were inundated; about 10 percent of this area was in urban and suburban developments. Lands along the smaller tributaries cannot be protected by the major flood control structures on the Willamette River and its major tributaries.

Forest Service

The Forest Service surveyed all National forest lands for damages sustained in the December 1964 and January 1965 floods. Storm damage to roads, trails, bridges, and improvements on those lands was estimated

Photo II-10 Storm damage to forest roads, trails, bridges, and improvements during the 1964 flood was extensive. (USBLM Photo)

to be $6-7 million. Damages to basic resources, although difficult to quantify, are estimated to be $1 million on National forest lands alone during these floods; this figure is based on a land loss of one percent and an average value of $40 per acre.

Federal Water Pollution Control Administration

Water and sewerage utilities are normally located near streams and are thus susceptible to flood damages such as clogging of conduits and other system appurtenances by sediment and complete destruction of major facilities by the force of the flood waters. Some adverse effects of flooding are experienced annually and are reluctantly accepted as normal. Although flood damage surveys are not normally made, FWPCA would probably be involved in evaluating damages sustained during emergencies such as the 1964-65 floods. This agency was not established until after those floods had occurred, and consequently did not make surveys.

Department of Health, Education and Welfare

The effects of the flood of 1964-1965 were documented by Federal-State inspection teams funded under provisions of Public Law 81-875. Damages were appraised for publicly owned facilities sustaining damages in excess of $1,000 for which the owners requested Federal aid for restoration of service. Damages to water and sewerage utilities, serving more than 830,000 persons were found to exceed $900,000. Many of the functions of HEW were later transferred to the Federal Water Pollution Control Administration, but the Department still has responsibility for determining health and sanitation conditions during floods.

EVACUATION OF FLOOD CONTROL STORAGE

Effective operation of reservoirs for flood control requires that flood waters stored during a storm be evacuated as soon as practicable after the flood has passed. Then storage space will be available to control runoff from any subsequent storm. In the Willamette Basin, this evacuation should be accomplished within 10 to 15 days.

As more flood control storage projects are completed, the evacuation flows become greater, particularly along Willamette River. Low-lying areas often remain inundated for several days as a result of these releases.

F L O O D   D A M A G E   R E D U C T I O N   M E A S U R E S

STRUCTURAL MEASURES

Structural measures to control floods are of three principal types: (1) reservoirs, which collect and store floodwaters; (2) channel improvements, which route floodwaters more efficiently; and (3) levees, floodwalls and revetments, which confine flood flows to a channel and protect flood-prone areas.

All Federally constructed water storage facilities in Willamette Basin are multipurpose projects providing storage for flood control and conservation uses. Privately owned power companies have constructed several dams and reservoirs for power production which provide some incidental and minor flood control. In addition, many small reservoirs have been constructed by local interests for stock watering, irrigation, recreation, and other purposes, and these also provide some flood control benefit. The floodwall along the west bank of Willamette River in downtown Portland protects against all but the largest floods.

More than $400 million have been expended by the Federal Government, under various agency programs, for construction of multipurpose reservoirs and other structural flood control measures in Willamette Basin. A description of the various facilities existing, under construction, and authorized is presented in Tables II-6 and -7.

Photo II-11 Channel improvements aid in the control of floods by routing floodwaters more efficiently. (USCE Photo)

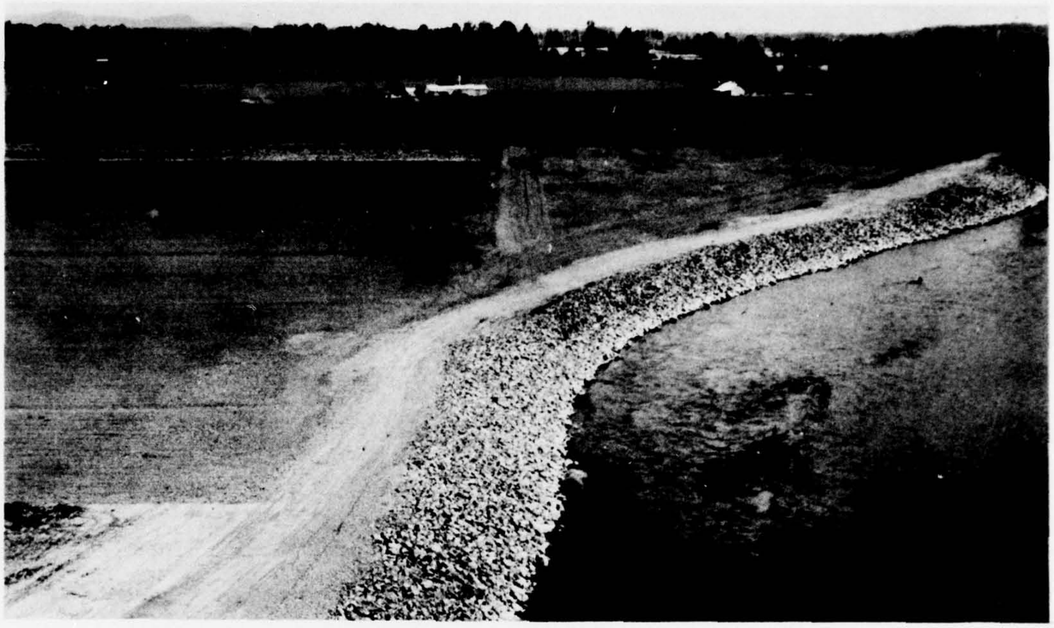


Photo II-12 Revetments protect eroding banks in flood-prone areas. (USCE Photo)

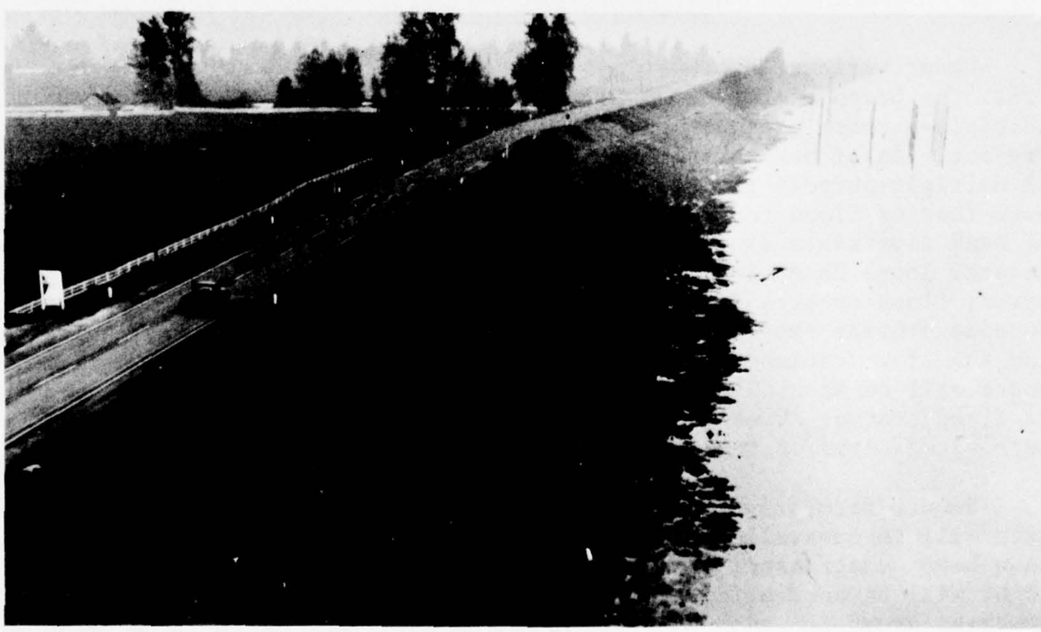


Photo II-13 Levees with bank revetment confine flood flows to the channel and protect flood-prone areas. (USCE Photo)

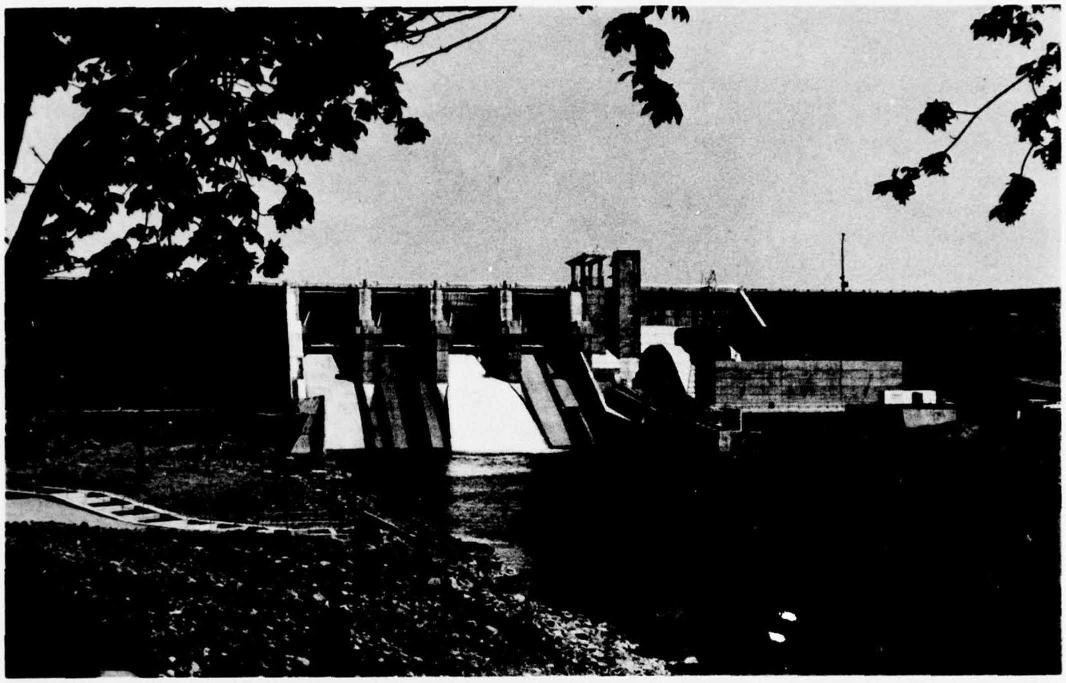
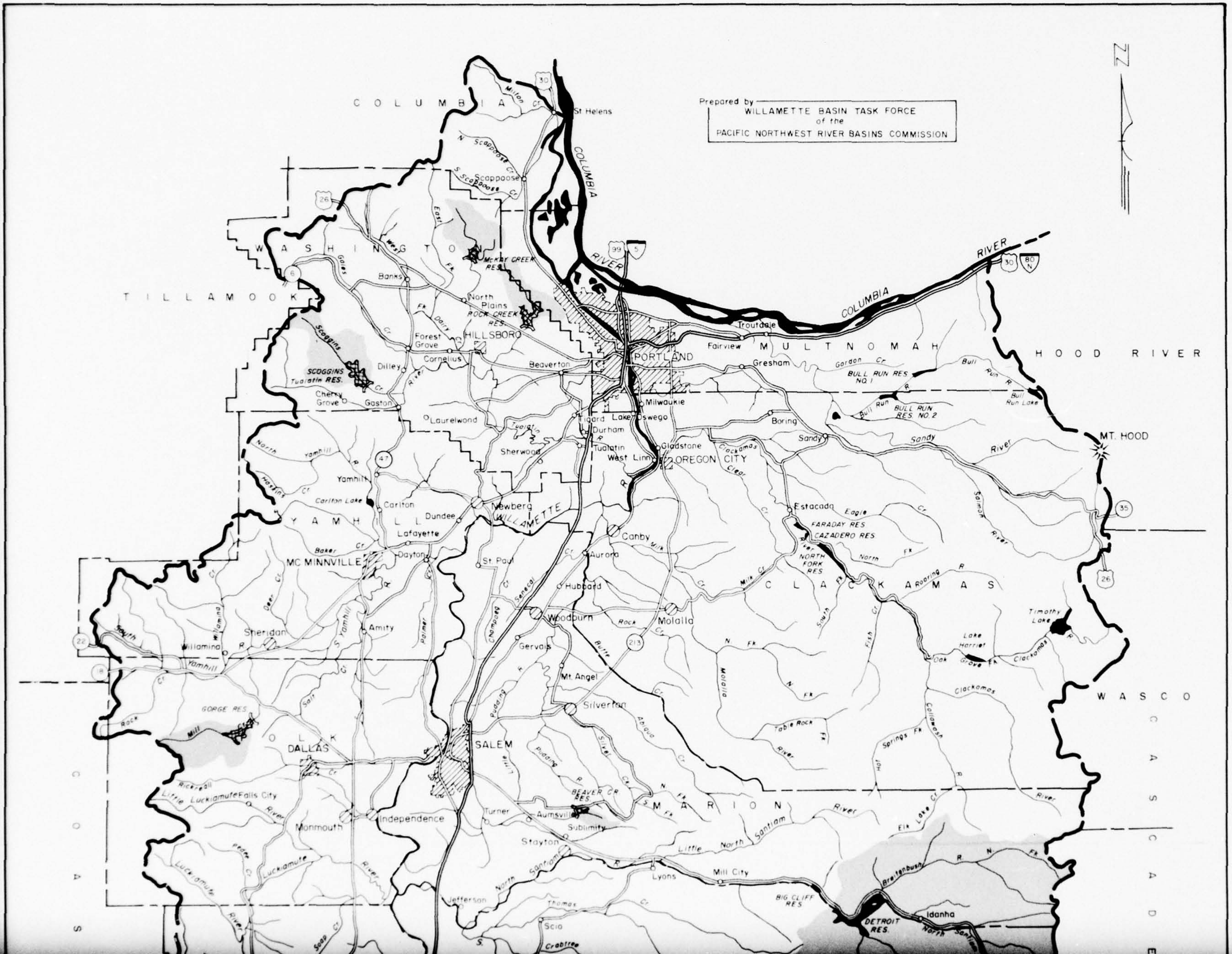


Photo II-14. Foster Dam (shown above), Green Peter (constructed), and Cascadia (authorized) are component reservoirs in a co-ordinated plan for flood control and multipurpose development of the South Santiam River Basin. (USCE Photo)

Willamette Basin Project

Under various Congressional authorizations dating from 1936 to 1962, the Corps of Engineers is constructing a system of single- and multiple-purpose projects generally referred to as the Willamette Basin Project. As of November 1968, the Willamette Basin Project included 11 multiple-purpose reservoirs which provided a total of 1.7 million acre-feet of flood control storage space (Map II-2), about 83 miles of bank revetments at 197 locations (Maps II-2a, 2b, and 2c) and several local channel improvements. Upon completion of the authorized works, flood control features of the project will include 14 multiple-purpose storage reservoirs, nearly 90 miles of bank protection facilities, and the aforementioned improved channels. Total flood control storage space will be about 2 million acre-feet, and the total cost allocated to flood control about $270 million. Pertinent data for existing and authorized Corps of Engineers reservoirs are presented in Table II-6.

Runoff from only about 29 percent of the Willamette Basin drainage area will be controlled even when all existing and authorized reservoirs have been constructed. The percentage of basin area from which runoff is or will be controlled by each unit is shown in Table II-6, and the drainage areas for each unit are shown on Map II-2. Most of the reservoirs are designed to completely control, at the damsite, a flood with an expected recurrence interval of about once in 100 years on the average. Flood control effects of the existing and authorized reservoirs are discussed in subsequent text.



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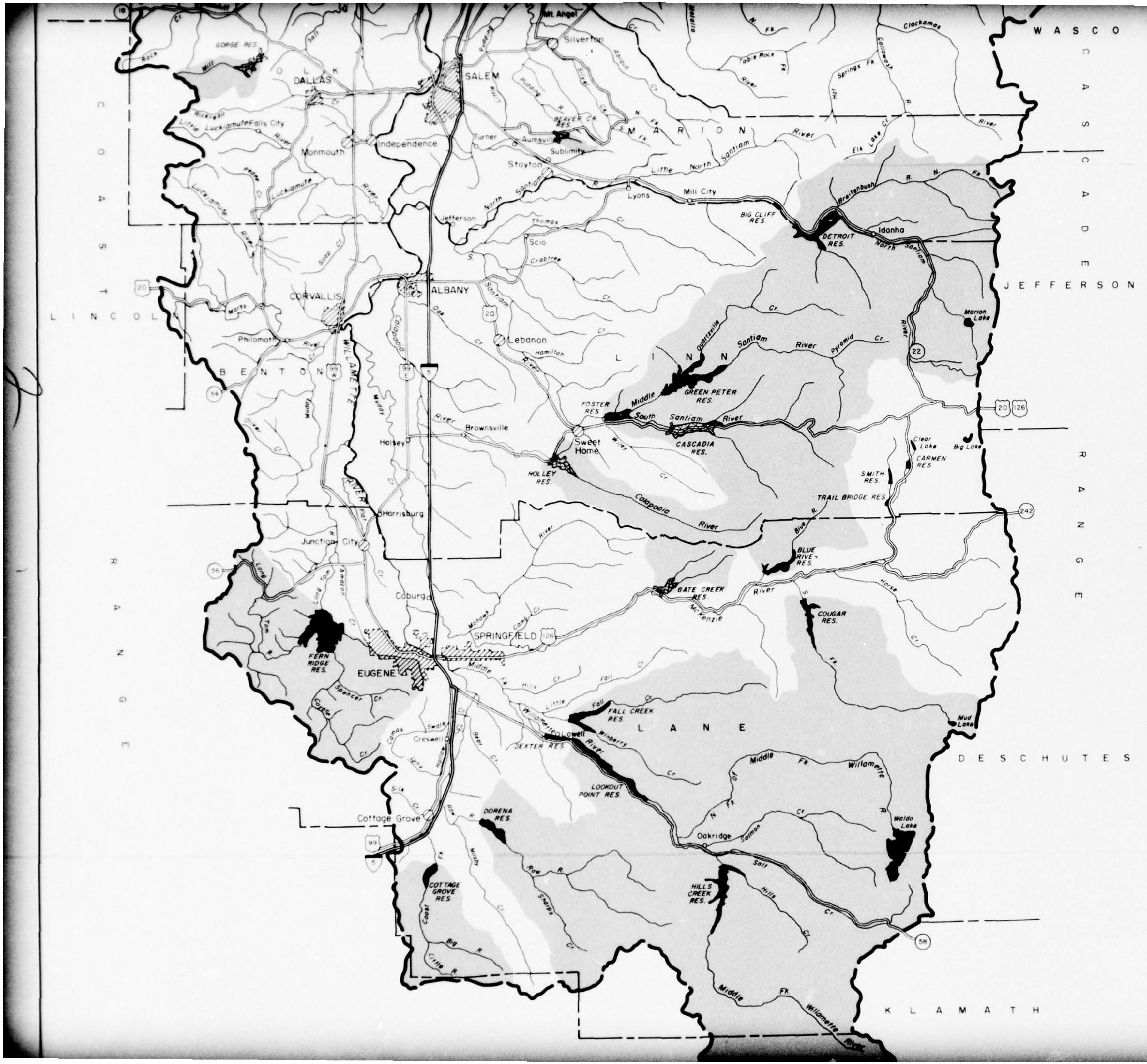
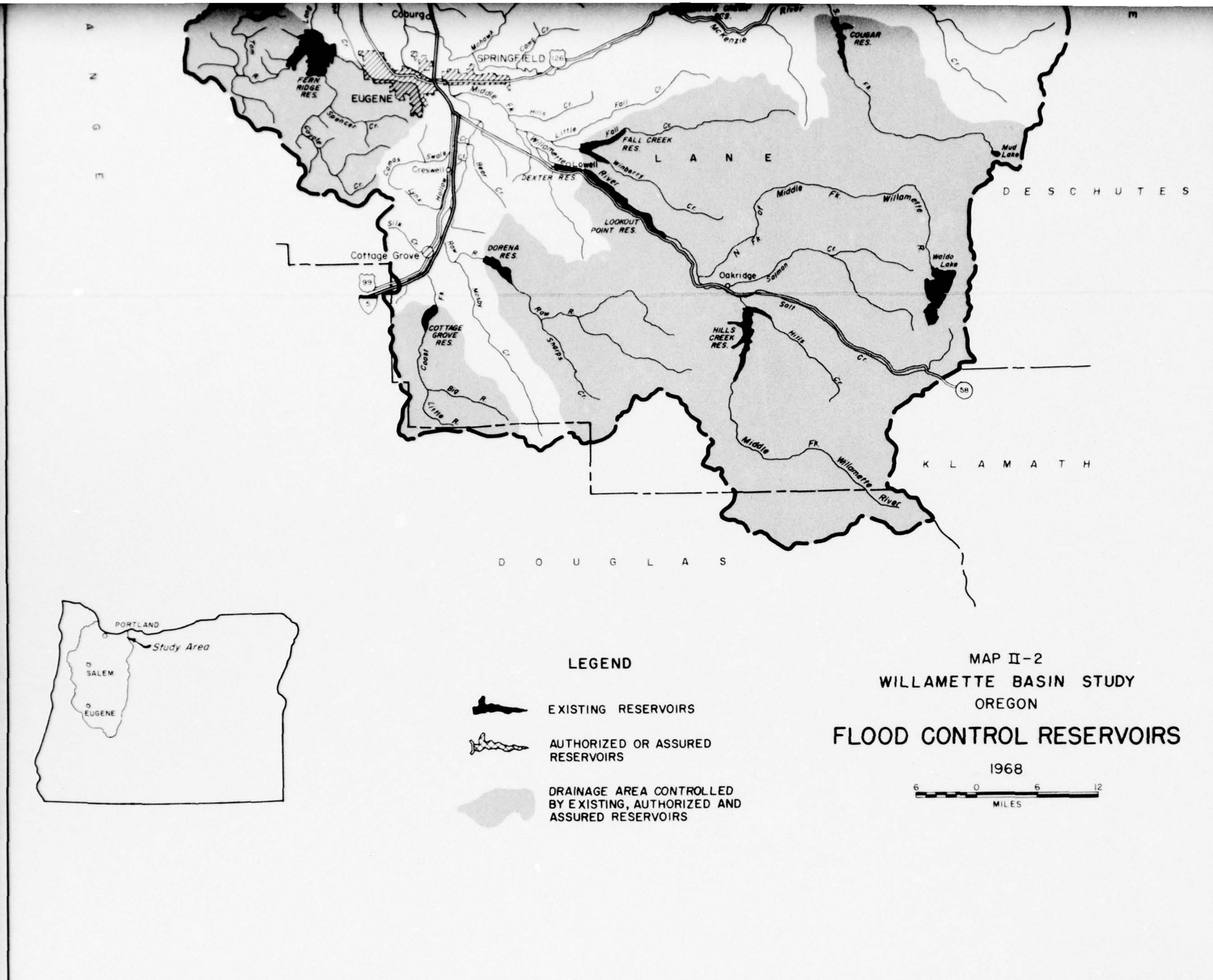
COLUMBIA
WASHINGTON
TILLAMOOK
MULTNOMAH
HOOD RIVER
YAMHILL
CLACKAMAS
WASCO
POLK
MARION
COAS
CASCADE
COLUMBIA RIVER
WILLAMETTE
MT. HOOD
St Helens
Scappoose
Banks
North Plains
HILLSBORO
Forest Grove
Cornelius
Dilley
Gaston
Cherry Grove
Beaverton
PORTLAND
Troutdale
Fairview
Gresham
Milwaukie
Lake Oswego
Tigard
Durham
Tualatin
West Linn
Gladstone
OREGON CITY
Boring
Sandy
Estacada
Laurelwood
Sherwood
Newberg
Dundee
Carlton
Yamhill
Lafayette
Dayton
MC MINNVILLE
Amity
Sheridan
Willamina
St. Paul
Aurora
Canby
Hubbard
Woodburn
Molalla
Gervais
Mt. Angel
Silverton
SALEM
DALLAS
Falls City
Monmouth
Independence
Turner
Aumsville
Sublimity
Stayton
Lyons
Mill City
Jefferson
Scio
Idanha
McKAY CREEK RES.
ROCK CREEK RES.
SCOGGINS RES.
BULL RUN RES NO. 1
BULL RUN RES. NO. 2
Bull Run Lake
FARADAY RES
CAZADERO RES
NORTH FORK RES
Timothy Lake
Lake Harriet
Carlton Lake
GORGE RES.
BEAVER CR RES
BIG CLIFF RES
DETROIT RES.



WASCO
CASCADE
JEFFERSON
RANGE
DESCHUTES
KLAMATH
COAST
RANGE
LINCOLN
POLK
MARION
LINN
BENTON
LANE
Silverton
Mt. Angel
SALEM
DALLAS
Independence
Monmouth
Falls City
Turner
Aumsville
Sublimity
Stayton
Lyons
Mill City
Idanha
Jefferson
Scio
ALBANY
CORVALLIS
Philomath
Lebanon
Brownsville
Halsey
Harrisburg
Junction City
Coburg
Sweet Home
SPRINGFIELD
EUGENE
Creswell
Cottage Grove
Oakridge
Lowell
GORGE RES.
BEAVER CR RES
BIG CLIFF RES
DETROIT RES.
GREEN PETER RES.
FOSTER RES
CASCADIA RES.
HOLLEY RES.
SMITH RES.
CARMEN RES
TRAIL BRIDGE RES
BLUE RIVER RES
GATE CREEK RES
COUGAR RES.
FERN RIDGE RES.
FALL CREEK RES.
DEXTER RES
LOOKOUT POINT RES.
DORENA RES
COTTAGE GROVE RES.
HILLS CREEK RES.
Marion Lake
Clear Lake
Big Lake
Mud Lake
Waldo Lake
WILLAMETTE RIVER
Santiam River
Calapooia River
McKenzie River
Middle Fk Willamette R



LEGEND

EXISTING RESERVOIRS

AUTHORIZED OR ASSURED RESERVOIRS

DRAINAGE AREA CONTROLLED BY EXISTING, AUTHORIZED AND ASSURED RESERVOIRS

MAP II-2
WILLAMETTE BASIN STUDY
OREGON

FLOOD CONTROL RESERVOIRS

1968

6 0 6 12
MILES

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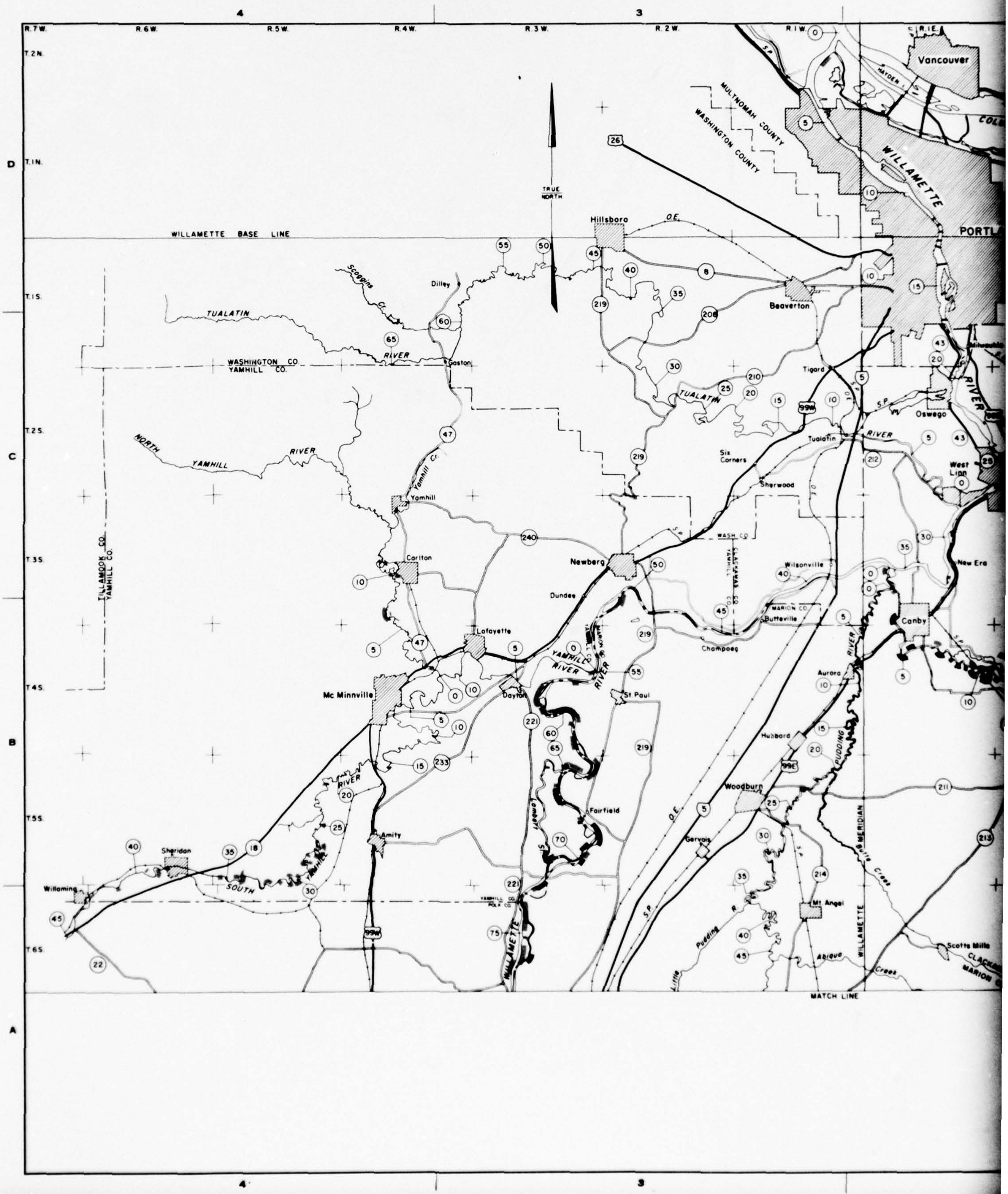
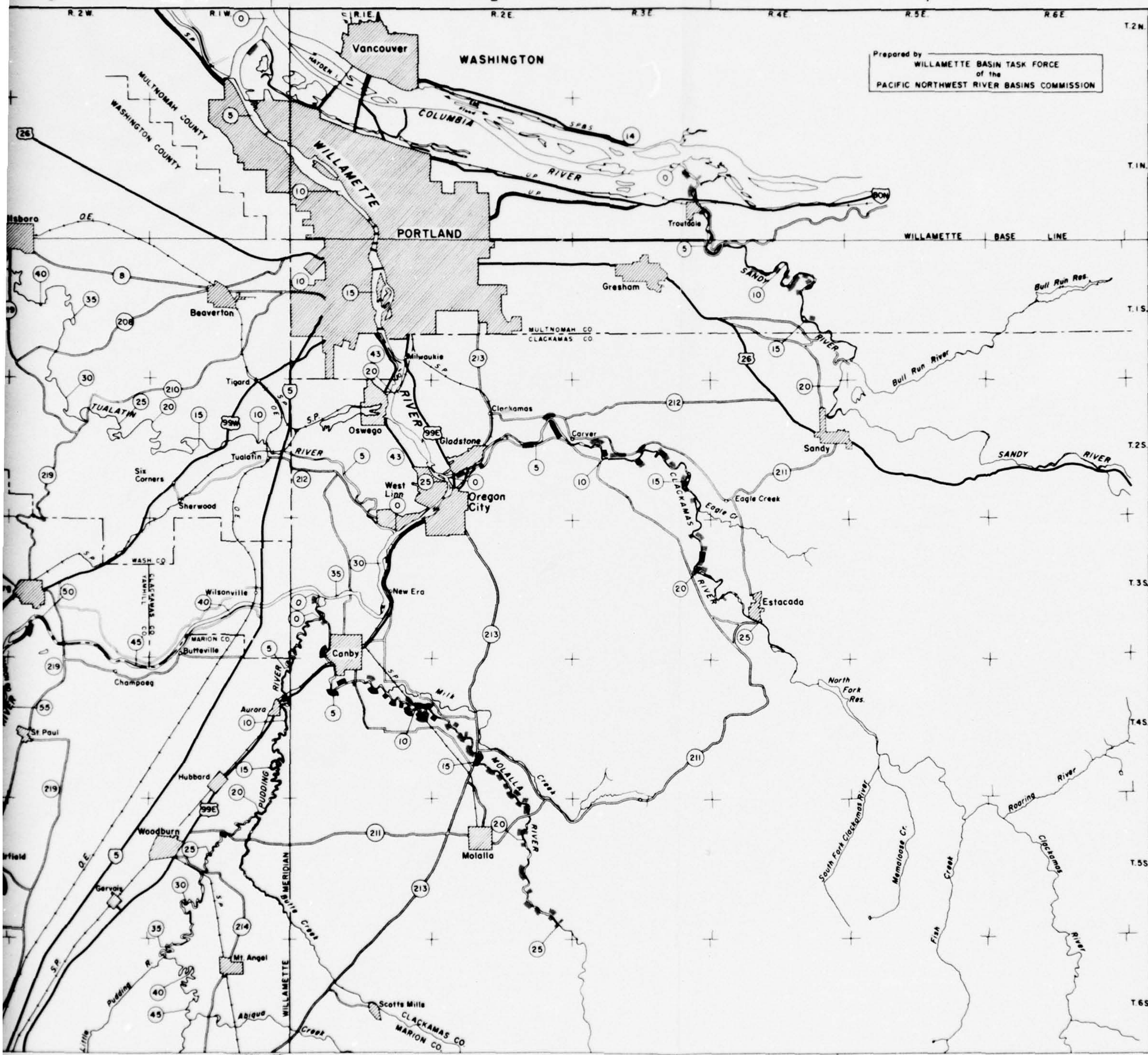
3



4
3
R.7W.
R.6W.
R.5W.
R.4W.
R.3W.
R.2W.
R.1W.
R.1E.
T.2N.
T.1N.
T.1S.
T.2S.
T.3S.
T.4S.
T.5S.
T.6S.
D
C
B
A
TRUE NORTH
WILLAMETTE BASE LINE
Vancouver
MULTNOMAH COUNTY
WASHINGTON COUNTY
WILLAMETTE
PORTLA
Hillsboro
Beaverton
Dilley
Scoggins Cr.
TUALATIN
RIVER
WASHINGTON CO.
YAMHILL CO.
Gaston
Tigard
TUALATIN
Tualatin
RIVER
Oswego
West Linn
Six Corners
Sherwood
NORTH
YAMHILL
RIVER
Yamhill
Carlton
Newberg
Dundee
Wilsonville
New Era
Butteville
Champoeg
Canby
Lafayette
YAMHILL
RIVER
Mc Minnville
Dayton
St Paul
Aurora
Hubbard
Woodburn
Gervais
Fairfield
Amity
Sheridan
Willamina
SOUTH
YAMHILL
RIVER
Mt Angel
Scotts Mills
TILLAMOOK CO.
YAMHILL CO.
YAMHILL CO.
POLK CO.
WILLAMETTE
WILLAMETTE MERIDIAN
Pudding R.
Abiqua
Creek
MATCH LINE



MAP II - 2a

WILLAMETTE BASIN STUDY

OREGON

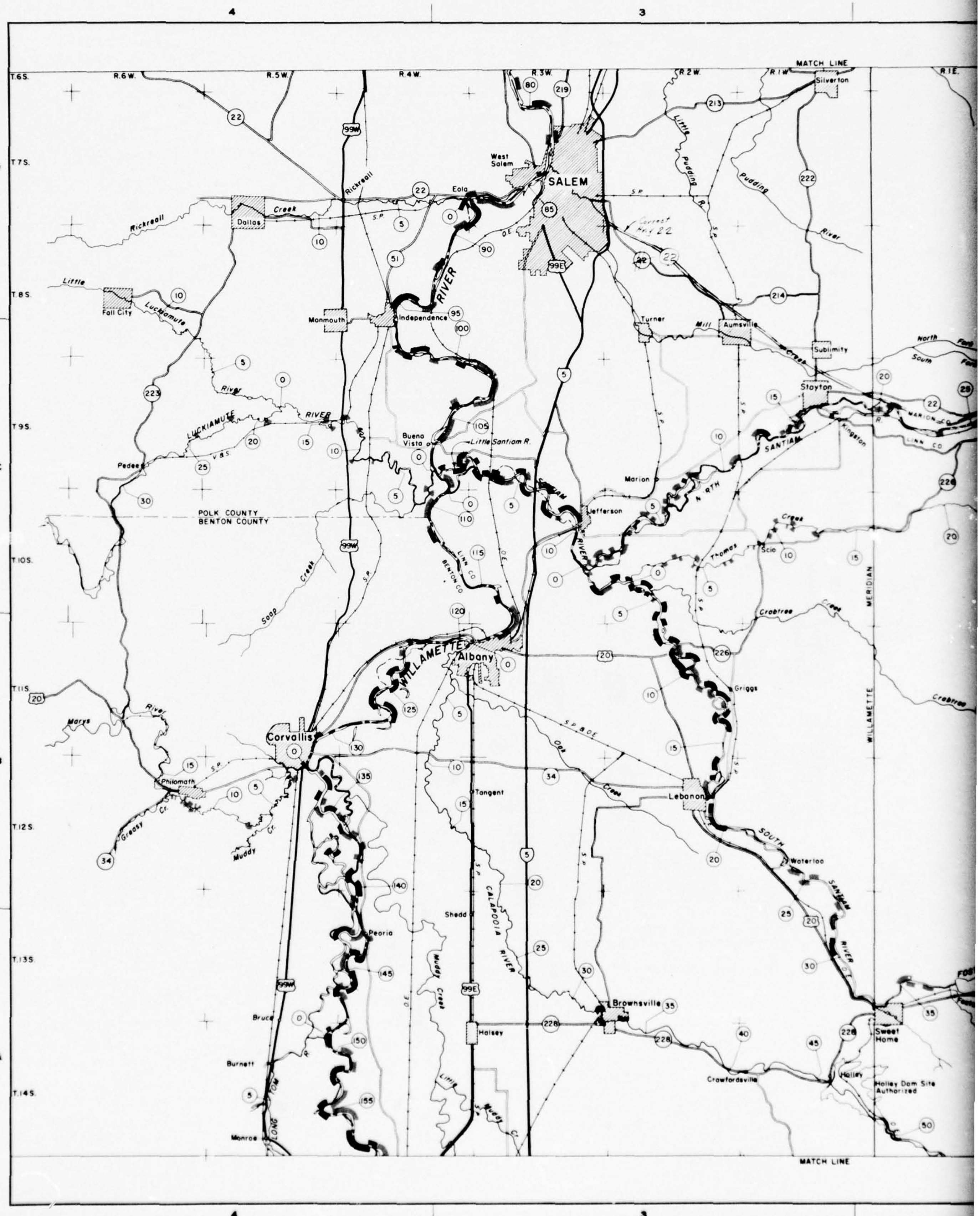
BANK STABILIZATION

1969

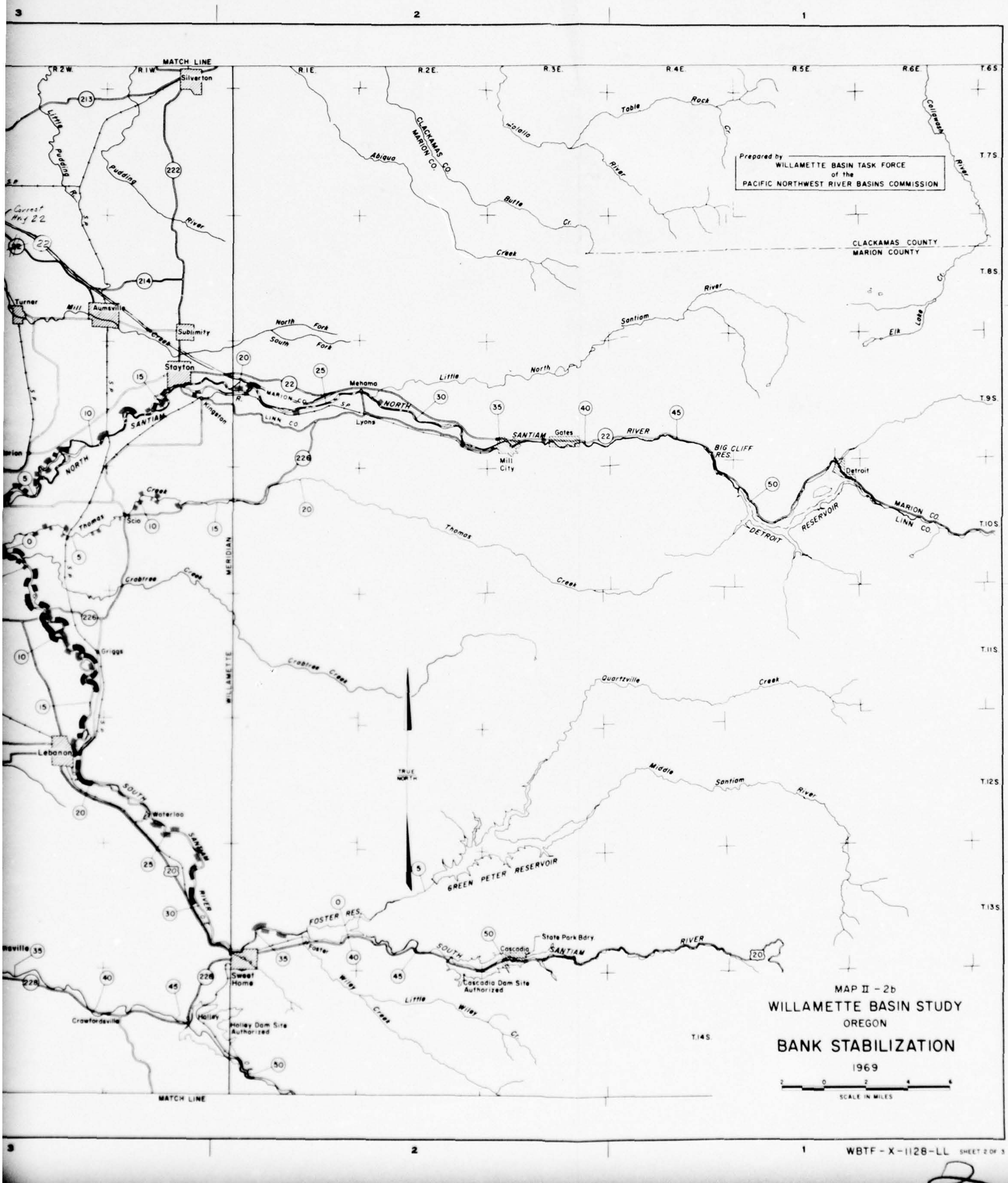
LEGEND

- Existing Bank Stabilization
- Erosion Areas

WBTF-X-1128-LL SHEET 1 OF 3



4
3
MATCH LINE
T.6S.
R.6W.
R.5W.
R.4W.
R.3W.
R.2W.
R.1W.
R.1E.
Silverton
D
T.7S.
West Salem
SALEM
Rickreall
Eola
Dallas
Rickreall
Creek
S.P.
Little
Pudding
R.
Pudding
River
Current Hwy 22
T.8S.
Little
Luckiamute
Fall City
Monmouth
Independence
RIVER
Turner
Mill
Aumsville
Sublimity
Creek
North
South
Stayton
Kingston
MARION CO.
LINN CO.
River
LUCKIAMUTE
RIVER
T.9S.
Buena Vista
Little Santiam R.
SANTIAM
Pedee
C
POLK COUNTY
BENTON COUNTY
Marion
Jefferson
Creek
Scio
Thomas
T.10S.
LINN CO
BENTON CO
Soap
Creek
MERIDIAN
Crabtree
Creek
WILLAMETTE
Albany
T.11S.
Marys
River
Griggs
Crabtree
Corvallis
B
Philomath
S.P.
Tangent
S.P. & O.E.
Oak
Creek
Lebanon
T.12S.
Greasy
Cr.
Muddy
Cr.
SOUTH
Waterloo
SANTIAM
RIVER
Shedd
CALAPOOIA
RIVER
Peoria
T.13S.
Muddy
Creek
Brownsville
Bruce
Halsey
Sweet Home
A
Burnett
Crawfordsville
Holley
Holley Dam Site Authorized
T.14S.
LONG TOM
Little
Muddy
Cr.
Monroe
MATCH LINE
4
3



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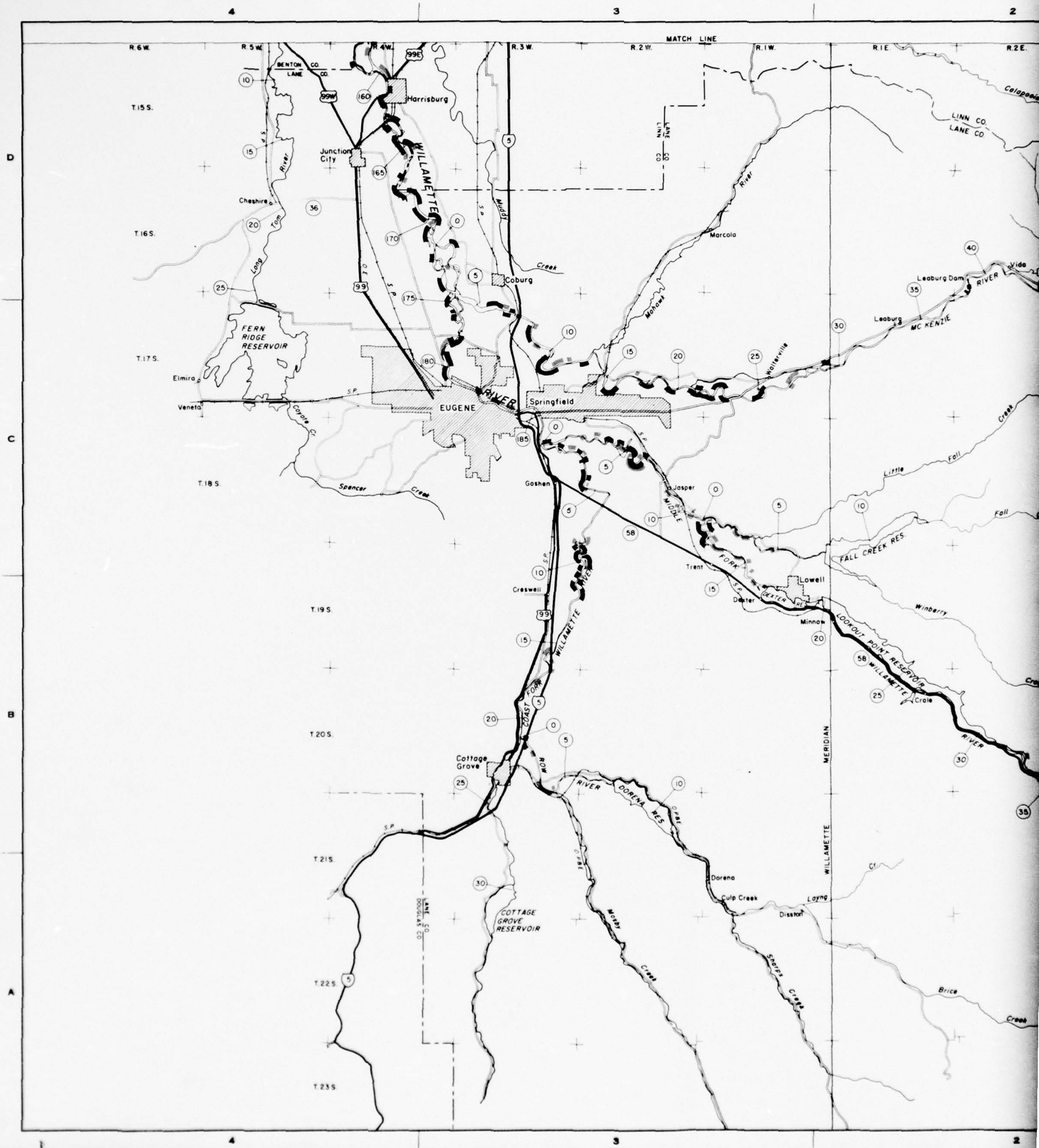
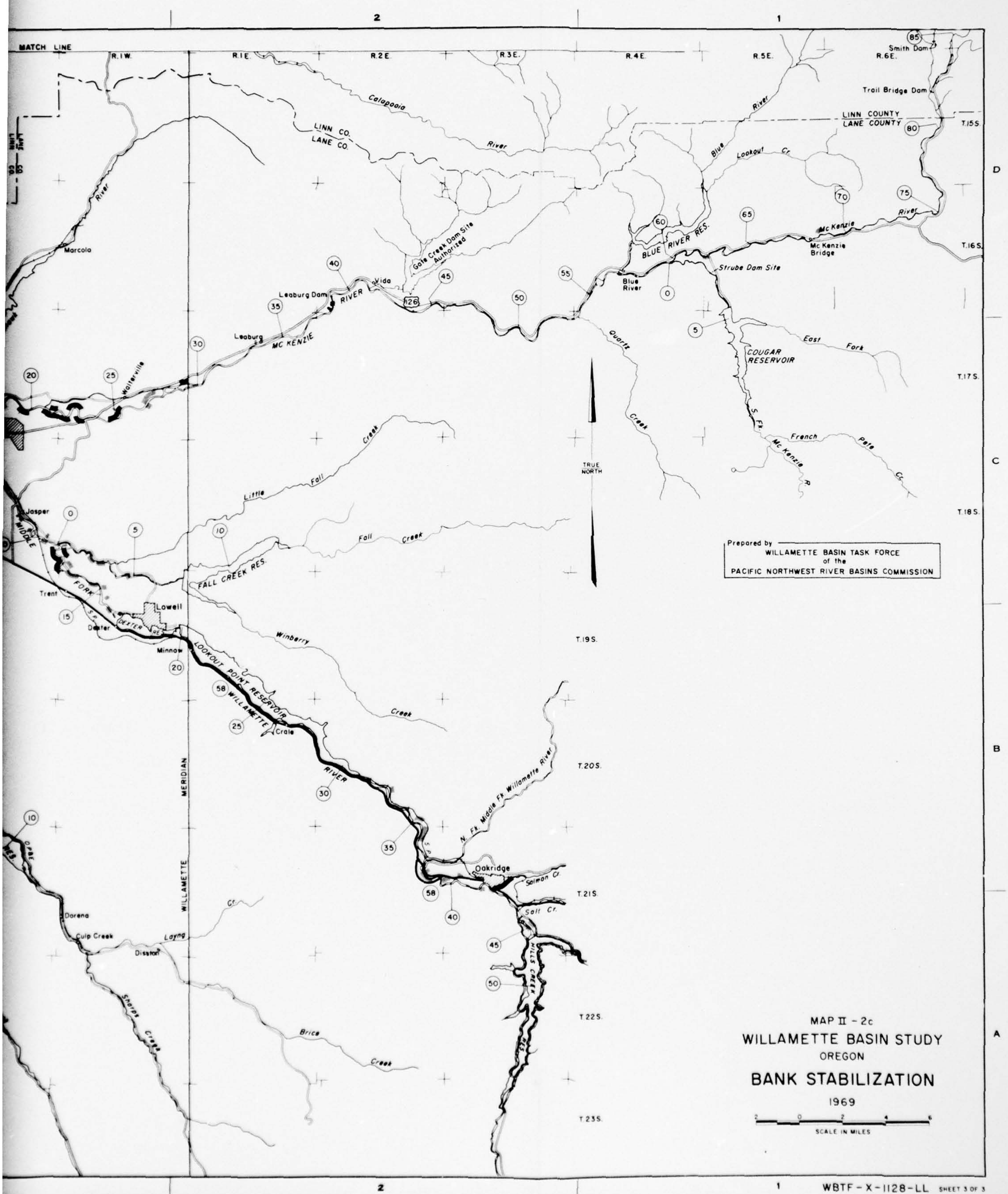
MATCH LINE
Silverton
Turner
Aumsville
Sublimity
Stayton
Mehama
Lyons
Kingston
Mill City
Gates
Detroit
Scio
Griggs
Lebanon
Waterloo
Sweet Home
Foster
Cascadia
Crawfordsville
Holley
Holley Dam Site Authorized
Cascadia Dam Site Authorized
State Park Bdry
BIG CLIFF RES.
DETROIT RESERVOIR
GREEN PETER RESERVOIR
FOSTER RES.
CLACKAMAS COUNTY
MARION COUNTY
CLACKAMAS CO.
MARION CO.
LINN CO.
WILLAMETTE MERIDIAN
TRUE NORTH
NORTH SANTIAM RIVER
SOUTH SANTIAM RIVER
Middle Santiam River
Little North Santiam River
Quartzville Creek
Thomas Creek
Crabtree Creek
Table Rock Cr.
Molalla River
Abiqua
Butte Cr.
Pudding River
Little Pudding R.
Mill Creek
Wiley Creek
Little Wiley Cr.
Elk Lake Cr.
Collawash River
North Fork
South Fork
MAP II - 2b
WILLAMETTE BASIN STUDY
OREGON
BANK STABILIZATION
1969
SCALE IN MILES
WBTF - X - 1128 - LL SHEET 2 OF 3



MATCH LINE
R.6W.
R.5W.
R.4W.
R.3W.
R.2W.
R.1W.
R.1E.
R.2E.
T.15S.
T.16S.
T.17S.
T.18S.
T.19S.
T.20S.
T.21S.
T.22S.
T.23S.
BENTON CO.
LANE CO.
LINN CO.
LANE CO.
LANE CO.
DOUGLAS CO.
Harrisburg
Junction City
Cheshire
Coburg
Marcola
Elmira
Veneta
EUGENE
Springfield
Goshen
Jasper
Trent
Lowell
Dexter
Minnow
Creswell
Cottage Grove
Dorena
Culp Creek
Disston
Leaburg Dam
Leaburg
Vida
Walterville
Crale
FERN RIDGE RESERVOIR
COTTAGE GROVE RESERVOIR
FALL CREEK RES.
LOOKOUT POINT RESERVOIR
DEXTER RES.
DORENA RES.
WILLAMETTE
RIVER
MIDDLE FORK
COAST FORK
ROW RIVER
MC KENZIE RIVER
Long Tom River
Mohawk River
Muddy Creek
Coyote Cr.
Spencer Creek
Little Fall Creek
Fall
Winberry
Calapooia
Layng
Mosby Creek
Sharps Creek
Brice Creek
WILLAMETTE MERIDIAN
99W
99E
99
5
58
S.P.
O.E.



WBTF - X - 1128 - LL SHEET 3 OF 3

2

Table II-6

Corps of Engineers dam and reservoir projects

Reservoir	Stream	River Mile 1/	Area Controlled Sq. Mi.	Area Controlled Percent 2/	Area Normal Pool (acres)	Storage Capacity (acre-feet) Flood Control	Storage Capacity (acre-feet) Total	Share of Construction Cost Allocated to Flood Control (percent)	In Service for Flood Control (year)
			Existing Projects						
Fern Ridge	Long Tom R.	25.7	275	2.5	10,400	110,000	117,000	43	1941
Cottage Grove	Coast Fork Will. R.	29.7	104	0.9	1,158	30,000	33,000	49	1942
Dorena	Row River	7.6	265	2.4	1,840	70,500	77,500	57	1949
Detroit	N. Santiam R.	49.2	438	4.0	3,580	300,000	455,000	32	1953
Big Cliff (reregulating)					100	-	5,900		-
Lookout Point	Mid. Fk. Will. R.	19.9	991	8.8	4,360	337,000	456,000	55	1953
Dexter (reregulating)					1,025	-	27,500		-
Hills Creek	Mid. Fk. Will. R.	45.5	389 4/	4/	2,735	200,000	356,000	54	1961
Cougar	S. Fk. McKenzie River	4.5	208	1.9	1,280	155,000	219,000	63	1963
Fall Creek	Fall Creek	7.2	184	1.6	1,880	115,000	125,000	63	1965
Green Peter	Mid. Santiam R.	5.7	277 5/	5/	3,720	270,000	430,000	51	1967
Foster	S. Santiam R.	37.7	494	4.4	1,220	30,000	61,000		1967
Blue River	Blue River	1.7	88	0.8	975	85,000	89,000	70	1968
	Subtotal - Existing Projects		3,047	27.3		1,702,500	2,451,900		
			Authorized Projects						
Holley 3/	Calapooia R.	45.5	105	0.9	2,120	3/ 90,000	97,000 3/	3/	
Cascadia	S. Santiam R.	48.0	179 5/	5/	1,700	145,000	160,000	71	
Gate Creek	Gate Creek	0.4	50	0.4	605	50,000	55,000	61	
	Subtotal - Authorized Projects		155	1.3		285,000	312,000		
TOTAL			3,202	28.6		1,987,500	2,763,900		

1/ *River mileages as determined by Columbia Basin Interagency Committee (CBIAC), June 1963*
2/ *Refers to percent of area drained by Willamette River (11,200 square miles)*
3/ *Project being restudied - flood control storage needs are as shown*
4/ *Included in area upstream from Lookout Point*
5/ *Included in area upstream from Foster*

Reclamation Program

The Tualatin Project was authorized in 1966 for construction by the Bureau of Reclamation (P.L. 89-596). The project will provide incidental flood control for about 3-1/2 miles along Scoggins Creek, below Scoggins Dam. Allocated cost for flood control is $50,000 (January 1965 prices).

U. S. Department of Agriculture Programs

Under U. S. Department of Agriculture programs, individual landowners have applied vegetative and structural measures to control flooding. Expenditures since 1937 total about $19 million, of which the landowners contributed 50 percent. In 1963, landowners made improvements costing about $1 million, of which approximately 60 percent were for vegetative measures and 40 percent for structures.

The Upper Willamette Resource Conservation and Development Project was authorized in 1964, under provisions of the 1962 Food and Agriculture Act (Section 102, P.L. 87-703). Federal funds are provided through existing programs of other Federal agencies and through U.S.D.A. funds available to the Soil Conservation Service. Project purposes are carried out through local sponsoring organizations empowered to do so by State Law. Under this program, five small flood control projects have been planned, of which four are under construction and one is completed. Several others are in various stages of planning.

Photo II-15 A winter cover crop in an orchard reduces the hazard of scour from winter floods. (USSCS Photo)

Photo II-16 A cooperative drainage ditch gives drainage to individual farms and a channel for floodwaters. (USSCS Photo)

Since the enactment of P.L. 83-566 in 1954, the Soil Conservation Service has received applications for assistance from 14 watersheds in the Willamette Basin. All have listed flood control as their principal objective. The watersheds are shown on Map II-3. Projects administered by the Soil Conservation Service involving flood control are shown in Table II-7.

OTHER EXISTING DAMAGE REDUCTION MEASURES

Flood plain and watershed management, and flood forecasting and warning, as well as structural measures, play an important part in reducing flood damages and preventing loss of life.

Flood Plain Management

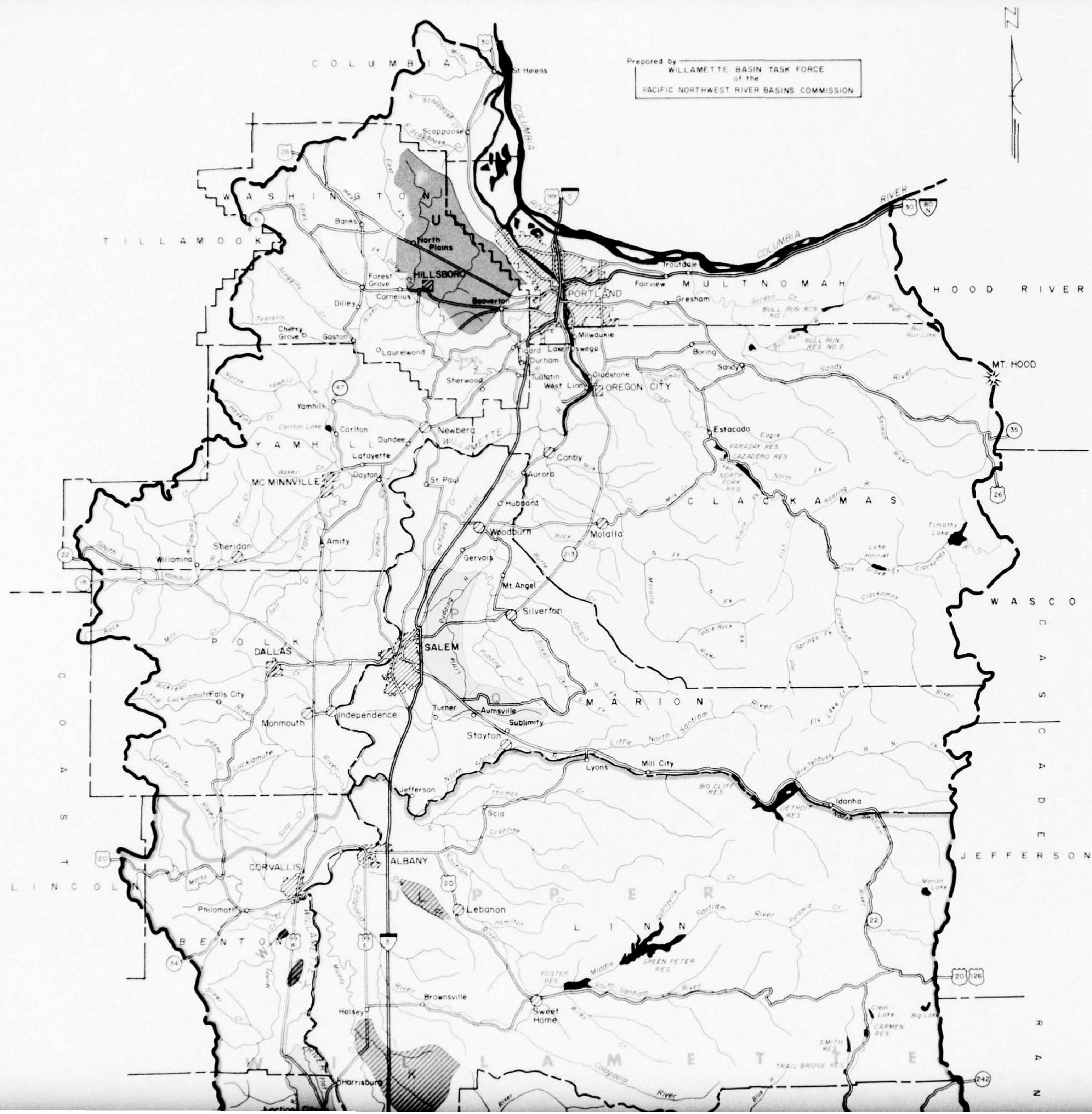
Flood plain management alleviates flood losses and flood hazards while promoting optimum use of flood plain lands. It includes actions to modify flood flows by flood control, to pass flood flows within designated floodways, and to modify flood-loss susceptibility by land use and occupancy regulations and by flood proofing.

Table II-7

RC&D and PL 83-566 projects

Project 1/	County	Sub-basin	Area (acres)	Type of Structure	Construction Status Start	Construction Status Complete	Share of Construction Cost Allocated to Flood Control (Percent)
				Existing Projects			
Lynx Hollow (B)	Lane	1	11,800	5 mi. channel improvement 2,000' concrete floodway	1963	1965	81
Lewellyn Road (W)	Benton	6	3,660	5.7 mi. channel improvement	1967	1968	100
Central District Flood Protection (H)	Lane	4	4,900	2.3 mi. channel improvement 4 grade-control structures	1966 1966	1966 1966	100
				Projects under Construction			
Willakenzie (E)	Lane	3,4	16,700	13 mi. channel improvement 8,000 ft. concrete 4,000 ft. earth dike	1960 1961 1959	- 1962 1960	81
Little Pudding River (P)	Marion	7	36,200	12 mi. channel improvement 2,400-HP pumping plant 7 water control structures 4 flood gates and dike	1963 1961 1963 1961	- 1962 1965 1962	88
Beaver Creek (Q)	Marion	7	19,900	6.4 mi. channel improvement	1963	1964	100
Lower Amazon-Flat Creek (J)	Lane	4	60,200	79 mi. channel improvement 2 Willamette channel closures	1968 -	- -	68
River Road (J_1)	Lane	4	680	8,900 ft. channel improvement	1968	-	100
Little Oak Creek (L)	Linn	5	3,500	4.5 mi. channel improvement	1968	-	100
Little Muddy Creek (K)	Linn	5	38,835	12 mi. channel improvement	1968	-	100
				Recommended Projects			
McKay-Rock Creek (U)	Washington	8	91,520	2 floodwater-retarding reservoirs 8 mi. channel improvements			14
Willamette City (X)	Lane	2	100	4,650 ft. concrete pipe			100
Winkle Butte (Y)	Benton	6	2,000	2.9 mi. channel improvement 2,100 ft. earth dike 1 water control structure			100
Dearborn Island (Z)	Lane	3	224,000	300-400 ft. protective dike 1,500 cu. yds. riprap			100

1/ *Letters in parenthesis following project name are codes for Map II-3, which shows the project locations*



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WASCO
CASCADE
JEFFERSON
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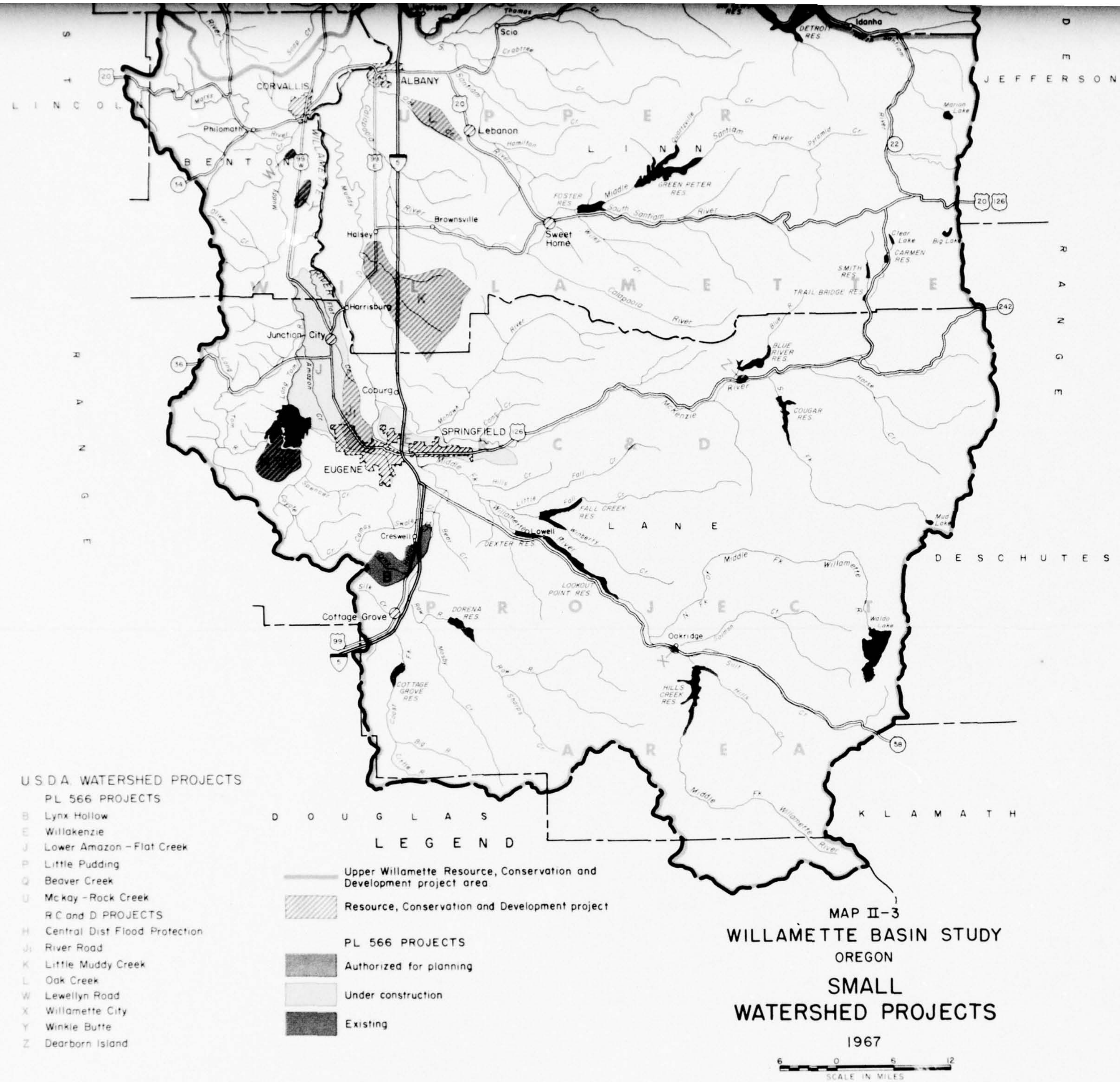
POLK
MARION
LINN
BENTON
LINCOLN
COAST
PORTLAND
SALEM
HILLSBORO
OREGON CITY
MC MINNVILLE
DALLAS
CORVALLIS
ALBANY
MT. HOOD
St Helens
Scappoose
Troutdale
Fairview
Gresham
Beaverton
North Plains
Forest Grove
Cornelius
Banks
Dilley
Gaston
Cherry Grove
Laurelwood
Sherwood
Tigard
Durham
Tualatin
Lake Oswego
Milwaukie
Gladstone
West Linn
Boring
Sandy
Estacada
Canby
Aurora
Hubbard
Woodburn
Molalla
Gervais
Mt Angel
Silverton
St Paul
Newberg
Dundee
Carlton
Yamhill
Lafayette
Dayton
Amity
Sheridan
Willamina
Falls City
Monmouth
Independence
Turner
Aumsville
Sublimity
Stayton
Lyons
Mill City
Idanha
Jefferson
Scio
Lebanon
Sweet Home
Brownsville
Halsey
Harrisburg
Philomath
BULL RUN RES NO 1
BULL RUN RES NO 2
FARADAY RES
CAZADERO RES
NORTH FORK RES
BIG CLIFF RES
DETROIT RES
GREEN PETER RES
FOSTER RES
SMITH RES
TRAIL BRIDGE RES
CARMEN RES
Timothy Lake
Lake Harriet
Marion Lake
Clear Lake
Big Lake
COLUMBIA RIVER
WILLAMETTE
Tualatin
Yamhill
Clackamas
Molalla
Pudding
Santiam
Luckiamute
Calapooia



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Watershed Management

Reduction of streamflows and accompanying flood and sediment damage on forested lands can be, and is being, accomplished by watershed management. Suitable methods of harvesting and reforesting these lands, clearing and maintaining stream channels, constructing channel works, and special land-treatment measures all contribute to more stabilized streamflow during flood periods. Flood debris may be substantially reduced by removing cull logs, branches, and tops left after logging from locations where they could be carried into stream channels, and by removing existing log jams and debris from stream channels. Owners of public and large private forests, in particular, are practicing watershed management techniques on their lands. The U. S. Department of Agriculture also has an extensive land-treatment program designed to reduce surface runoff and erosion on agricultural and urban lands. Technical assistance is provided to landowners. The land measures affect the quantity, quality, and seasonal distribution of the water resource. The primary effect of good watershed management with respect to flood control is to reduce accelerated erosion and scour, which in turn reduces sediment loading of streams and downstream deposition. For detailed discussion of watershed management, see Appendix G - Land Measures and Watershed Protection.

Photo II-17. Huge amounts of logs and debris accumulated at numerous reservoirs in the basin during the 1964 flood. (Oregonian Photo)

Photo II-18 Sandbagging the seawall at Portland after receiving flood warnings. (USCE Photo)

Flood Forecasting and Warning

Since its establishment in 1891, the Weather Bureau has had national responsibility for issuing flood warnings to the public. Warnings afford opportunity for preparation to withstand a flood event. Measures which can be taken before a flood include evacuation, rescheduling of operations, rerouting of transport, and flood fighting by temporary works (barriers, sandbagging, boarding-up, and others). Further, where flood control structures are in place, streamflow forecasts enable the reservoir operators to achieve maximum control of flood waters with the storage space available.

The Portland River Forecast Center, under the U. S. Weather Bureau of Environmental Science Services Administration, Department of Commerce, is the agency responsible for providing public forecasts of streamflow conditions in the Willamette Basin as well as for the entire Columbia River Basin and adjacent coastal basins. Figure II-2 shows the flow of data and forecasts in a typical hydrologic forecast system. Under a 1962 agreement, the U. S. Weather Bureau River Forecast Center and the North Pacific Division, U. S. Army Corps of Engineers, established the Cooperative Columbia River Forecast Unit to meet the functional requirements of both agencies. The overall objectives of the unit are: (1) to make the best use of available computer facilities and trained river forecasters as related to river management; (2) to advance techniques in all phases of river forecasting as related to river management; (3) to provide coordinated operational forecasts on a long, medium, and short-range basis for the common use of both agencies in meeting their respective missions; and (4) to centralize the river intelligence in

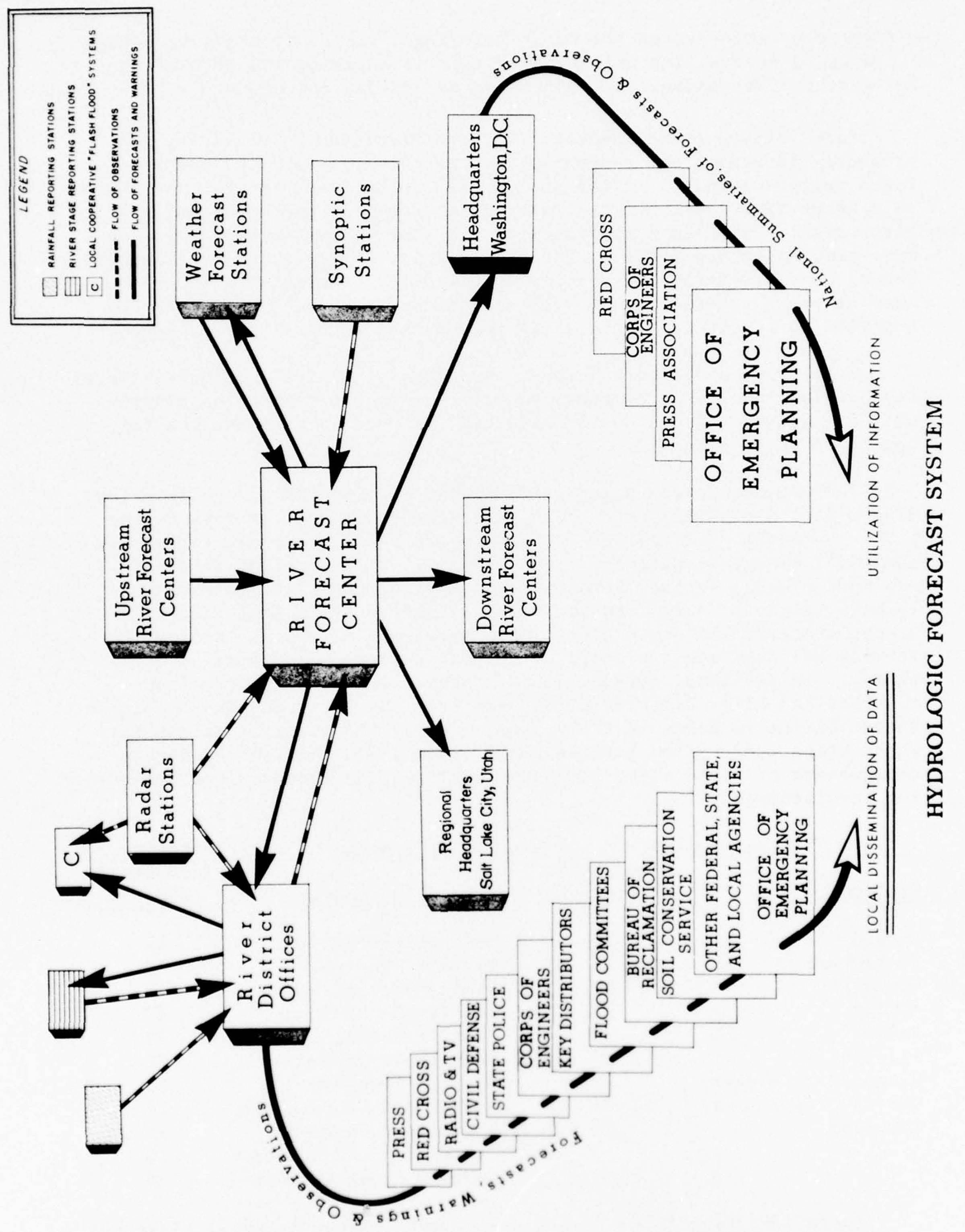


Figure II-2 Hydrologic Forecast System

a river operation center for daily briefings. Aside from the economies achieved, a forecasting unit of this type is an essential part of an integrated river management system for day-to-day operation.

Flood stages on Willamette River are predicted by combining all tributary forecasts and computing the time it will take the water to reach various points. Stages and floods can be predicted because there is a known time lapse between rainfall or snowmelt and the resulting river rise. This lapse increases as the river grows larger, allowing more time to make a forecast and act upon it. For each major tributary basin, past streamflow records are studied to establish the relationship of storm precipitation, soil conditions, and temperatures to the quantity of runoff and the time it reaches the tributary river gage.

Some river and rainfall gages have provisions for remote interrogation, which enables forecasters to keep "up to the minute" on progress of flood crests. Radar, a valuable aid, is used to estimate the rate and coverage of rainfall.

The Weather Bureau District Office in Portland is responsible for dissemination of Willamette Basin river forecasts and warnings to the public by radio, television, and newspapers and to Federal, State, and municipal emergency planning groups (Fig. II-2). Forecast releases are made via the Weather Bureau Oregon Agricultural Meteorological Teletype Circuit, which reaches many Willamette Basin radio and television stations and the national news services. Drops on this public-service teletype are available to any subscriber at a nominal monthly charge. In addition, forecasts are disseminated by telephone from the Portland River District Office and from the Salem and Eugene Weather Bureau Office to users in their local areas. The specific points for which stage and/or flow forecasts are issued, and the Weather Bureau designation of flood stage for each location, are shown in the following tabulation:

Willamette River		Willamette River Tributaries	
Station	Flood Stage (feet)	Stream and Station	Flood Stage (feet)
Eugene	23	McKenzie R.-Coburg	11
Harrisburg	12	Marys R.-Philomath	20
Corvallis	20	Santiam R.-Jefferson	15
Albany	25	Luckiamute R.-Suver	27
Salem	28	Yamhill R.-Whiteson	38
Wilsonville	25	Pudding R.-Aurora	20
Oregon City (Upper)	14	Molalla R.-Canby	13
Oregon City (Lower)	27	Tualatin R.-Farmington	29
Portland	18	Tualatin R.-Oswego	20
		Clackamas R.-Clackamas	13
		Johnson Creek-Sycamore	8

These foregoing flood stages are somewhat above bankfull stage but well below major flood stage and are the stages at which the Weather Bureau feels warnings are necessary.

ACCOMPLISHMENTS

Structural Measures

Flood Stage Reduction

The multiple-purpose reservoirs in Willamette Basin are effective in reducing flood stages in the stream reaches affected. Further reductions will result as additional units are constructed. Stage reductions brought about by reservoir regulation during the 1964 flood are shown in Figure II-3.

As units have been progressively added to the Corps of Engineers Willamette Basin Project, reductions in flood stages along Willamette River and controlled tributaries have become greater. Figures II-4a, 4b, and 4c--maximum annual stages of Willamette River at Salem, Albany, and Eugene, respectively--show considerable reduction of major flood stages and containment of lesser floods within the river banks, particularly at Eugene. Resource Conservation and Development projects and Small Watershed projects administered by the Soil Conservation Service exercise flood control principally on the tributary where the project is located, but the cumulative affect on damage reduction is considerable.

Flood stages have been considerably reduced at Salem, a representative station lying downstream from all existing major reservoirs. Here the flood stage in 1964 was reduced more than 7 feet by reservoir regulation. With the subsequent construction of Green Peter, Foster, Fall Creek, and Blue River Reservoirs, a similar flood stage at Salem would now be even further reduced. The unregulated and regulated maximum annual stages for overbank flows at Salem are shown in Table II-8.

Flood stages in 1964 were generally reduced more in the upper end of Willamette Valley than farther downstream (Fig. II-3). However, the reduction at Salem was slightly greater than at Albany because of the added effect of Detroit Reservoir on Santiam River and valley storage on Willamette River downstream from Albany. The reduction at Portland of 4.6 feet was somewhat less because of the uncontrolled tributaries feeding into the Willamette and some backwater effect from Columbia River.

Table II-8

Overbank flows at Salem

(Discharges in 1,000 cubic feet per second - stages in feet)

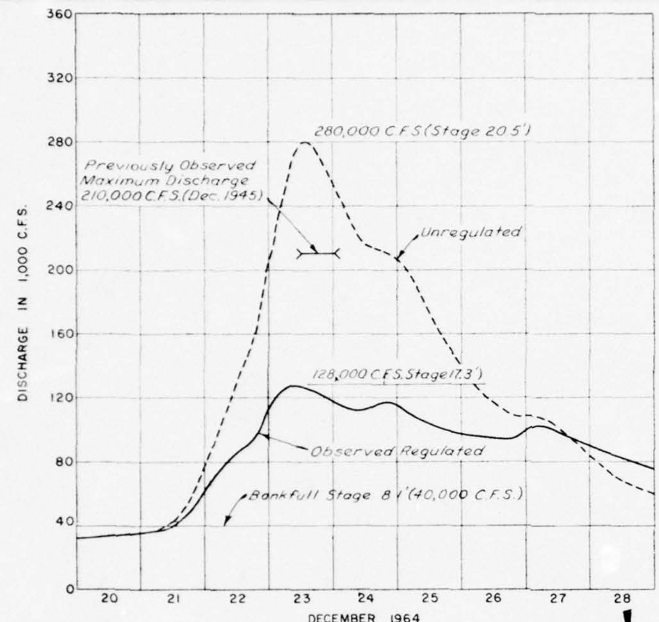
Date Mo.	Date Year	Unregulated Disch	Unregulated Stage	Regulated Disch	Regulated Stage
Jan	67	155.8	26.7	120.0	23.4
Jan	66	204.0	31.0	158.0	26.9
Jan	65	283.4	36.3	248.0	34.0
Dec	64	472.0	45.3	309.0	37.8
Jan	64	164.0	28.0	128.0	26.4
Feb	63	141.1	25.9	107.0	22.3
Mar	62	132.2	25.0	117.0	23.4
Dec	61	159.7	27.6	133.0	25.1
Nov	61	123.0	24.1	80.8	19.4
Feb	61	304.0	37.5	241.0	33.5
Nov	60	228.0	32.7	174.7	28.8
Feb	60	128.0	24.6	106.0	22.2
Jan	59	152.8	27.0	130.0	24.8
Nov	58	124.2	24.2	104.6	22.1
Jan	58	152.9	27.0	126.0	24.4
Dec	57	191.3	30.1	151.0	26.9
Mar	57	148.0	26.6	129.0	24.7
Feb	57	157.0	27.4	120.3	23.8
Dec	56	174.4	28.8	114.5	23.2
Jan	56	172.4	28.6	135.0	25.3
Dec	55	304.0	37.5	240.0	33.5
Dec	55	142.1	26.0	123.0	24.1
Nov	55	132.9	25.1	104.0	22.0
Jan	55	119.8	23.8	107.0	22.3
Jan	54	166.7	28.2	153.0	27.0
Dec	53	145.6	26.4	130.0	24.8
Dec	53	140.9	25.9	129.0	24.7
Nov	53	202.0	30.9	146.0	26.4
Feb	53	139.0	25.7	136.0	25.4
Jan	53	290.0	36.7	251.0	34.2
Feb	52	146.2	26.4	143.0	26.1

Date Mo.	Date Year	Unregulated Disch	Unregulated Stage	Regulated Disch	Regulated Stage
Dec	51	130.3	24.8	129.0	24.7
Jan	51	145.0	26.3	137.0	25.5
Dec	50	123.0	24.1	119.0	23.7
Nov	50	175.0	28.8	159.0	27.6
Feb	50	132.3	25.0	131.0	24.9
Jan	50	160.5	27.7	153.0	27.0
Feb	49	190.4	30.0	184.0	29.5
Dec	48	170.3	28.5	166.0	28.2
Jan	48	250.0	34.1	242.0	33.6
Dec	46	242.5	33.6	240.0	33.5
Nov	46	147.3	26.5	145.3	26.3
Dec	45	262.0	34.9	255.0	34.5
Nov	45	137.2	25.5	134.3	25.3
Jan	43	301.0	37.4	291.0	36.7
Nov	42	161.2	27.8	158.0	27.5
Dec	41	135.6	25.4	132.0	25.0
Mar	38	145.0	26.3		
Dec	37	186.0	29.7		
Apr	37	201.0	30.8		
Jan	36	225.0	32.5		
Jan	34	121.0	23.9		
Dec	33	175.0	28.8		
Mar	32	172.0	28.6		
Apr	31	220.0	32.1		
Nov	27	125.0	24.3		
Feb	27	243.0	33.7		
Feb	26	172.0	28.6		
Feb	25	178.0	29.1		
Jan	23	348.0	40.1		
Nov	21	219.0	32.1		
Dec	20	158.0	27.5		

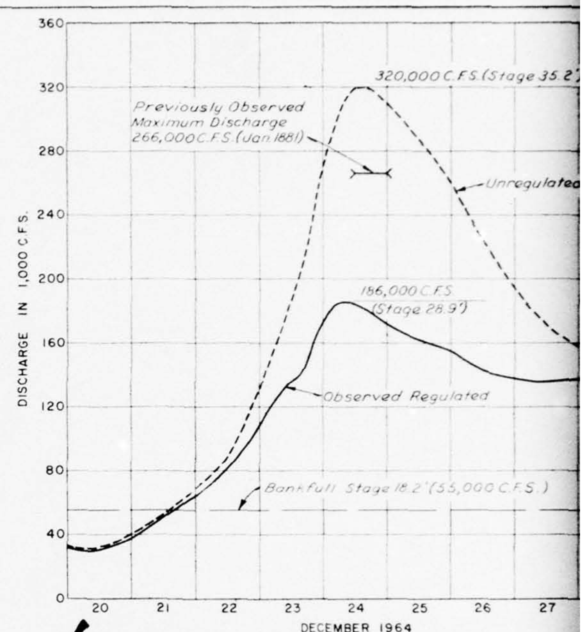
Date Mo.	Date Year	Unregulated Disch	Unregulated Stage	Regulated Disch	Regulated Stage
Jan	19	172.0	28.6		
Jan	18	141.0	25.9		
Dec	17	217.0	31.9		
Feb	16	242.0	33.6		
Mar	16	135.0	25.3		
Nov	15	122.0	24.0		
Jan	14	123.0	24.1		
Apr	13	158.0	27.5		
Jan	12	221.0	32.2		
Jan	11	155.0	27.2		
Mar	10	173.7	28.7		
Nov	09	315.0	38.2		
Jan	09	185.0	29.6		
Dec	08	224.0	32.4		
Mar	08	140.0	25.8		
Feb	07	325.0	38.8		
Feb	04	155.0	27.2		
Jan	03	283.0	36.3		
Dec	02	164.0	28.0		
Feb	02	122.0	24.0		
Jan	01	329.0	39.0		
Jan	00	178.0	29.1		
Mar	99	165.0	28.1		
Dec	98	137.0	25.5		
Feb	97	136.0	25.4		
Jan	96	176.0	28.9		
Jan	95	165.0	28.1		
Jan	94	246.5	33.9		
Dec	93	252.0	34.2		
Feb	90	448.0	45.1		
Jan	81	428.0	44.0		
Dec	61	500.0	47.0		

First major flood control reservoir constructed in 1941.

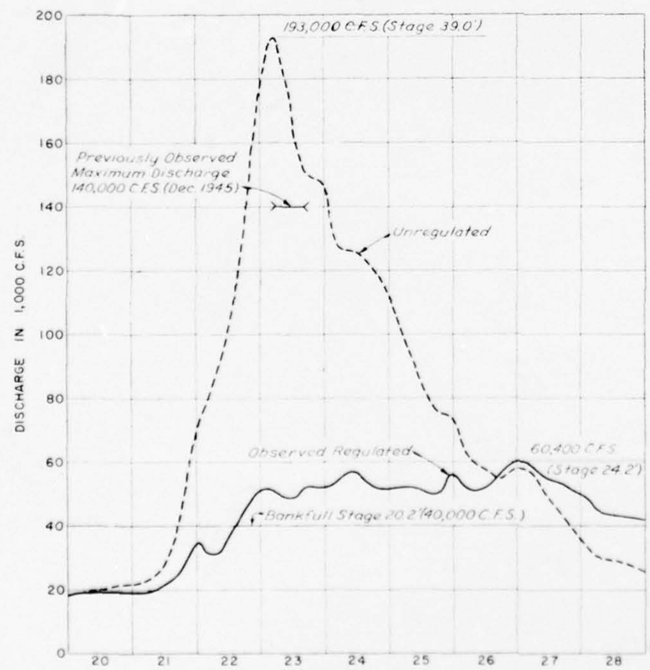
Note: *Stages based upon U. S. Geological Survey Rating Table 7, 12-9-65, reflect stage discharge relationships under existing conditions. For actual observed stages at time of occurrence refer to appropriate USGS Water Supply Paper or Rating Table. 0 gage = 106.14 feet (M.S.L.). Bankfull capacity at the Salem gage is taken as 120,000 cfs; however, bankfull capacity in the Salem reach is about 70,000 cfs. This list is not all inclusive prior to 1941.*



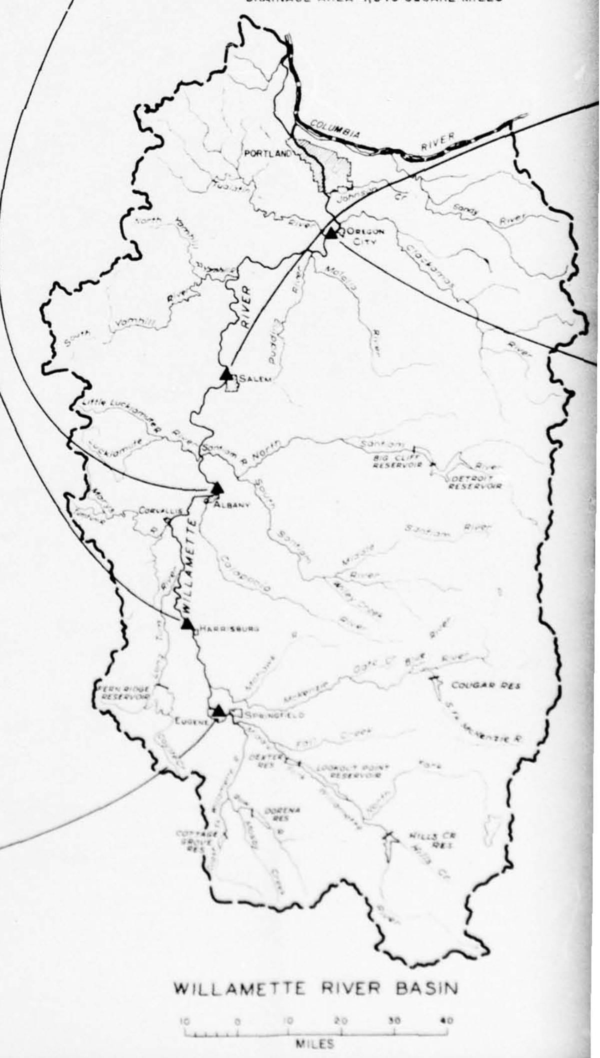
WILLAMETTE RIVER AT HARRISBURG, OREGON
DRAINAGE AREA 3,420 SQUARE MILES



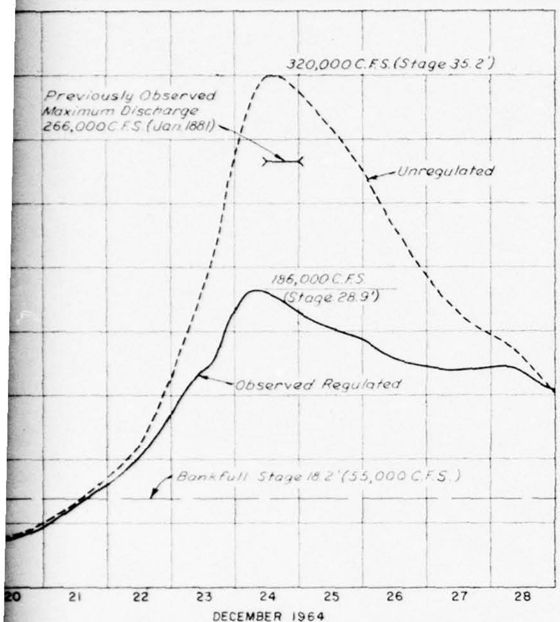
WILLAMETTE RIVER AT ALBANY, OREGON
DRAINAGE AREA 4,840 SQUARE MILES



WILLAMETTE RIVER AT EUGENE, OREGON
DRAINAGE AREA 2,072 SQUARE MILES

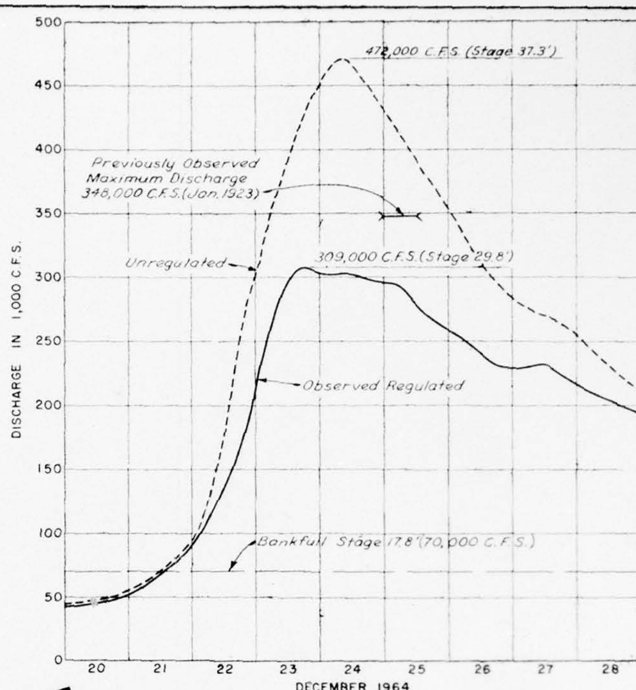


WILLAMETTE RIVER BASIN



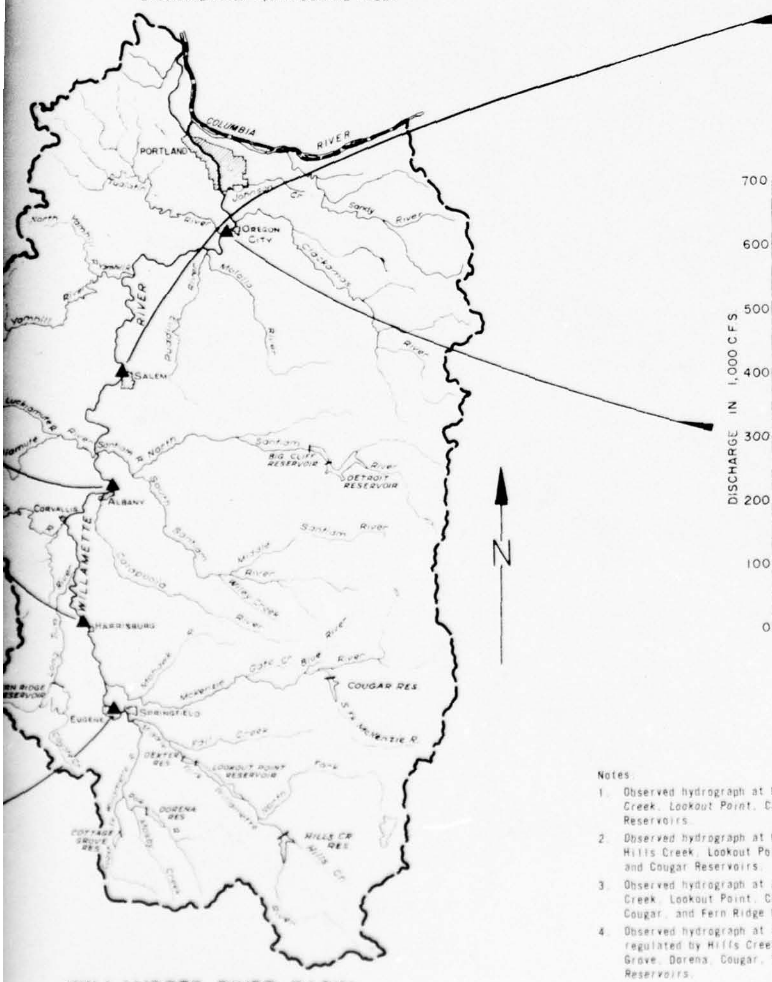
WILLAMETTE RIVER AT ALBANY, OREGON

DRAINAGE AREA 4,840 SQUARE MILES



WILLAMETTE RIVER AT SALEM, OREGON

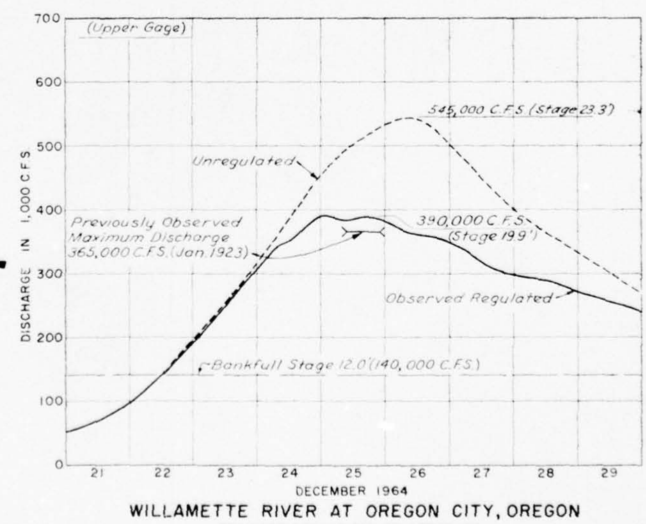
DRAINAGE AREA 7,280 SQUARE MILES



WILLAMETTE RIVER BASIN

10 0 10 20 30 40

MILES



WILLAMETTE RIVER AT OREGON CITY, OREGON

DRAINAGE AREA 10,098 SQUARE MILES

Notes:

1. Observed hydrograph at Eugene regulated by Hills Creek, Lookout Point, Cottage Grove, and Dorena Reservoirs.
2. Observed hydrograph at Harrisburg regulated by Hills Creek, Lookout Point, Cottage Grove, Dorena, and Cougar Reservoirs.
3. Observed hydrograph at Albany regulated by Hills Creek, Lookout Point, Cottage Grove, Dorena, Cougar, and Fern Ridge Reservoirs.
4. Observed hydrograph at Salem and Oregon City regulated by Hills Creek, Lookout Point, Cottage Grove, Dorena, Cougar, Fern Ridge, and Detroit Reservoirs.
5. Taken from Corps of Engineers drawing PD-26-3/8 corrected to reflect latest adjustments.

FIGURE II-3

WILLAMETTE BASIN STUDY

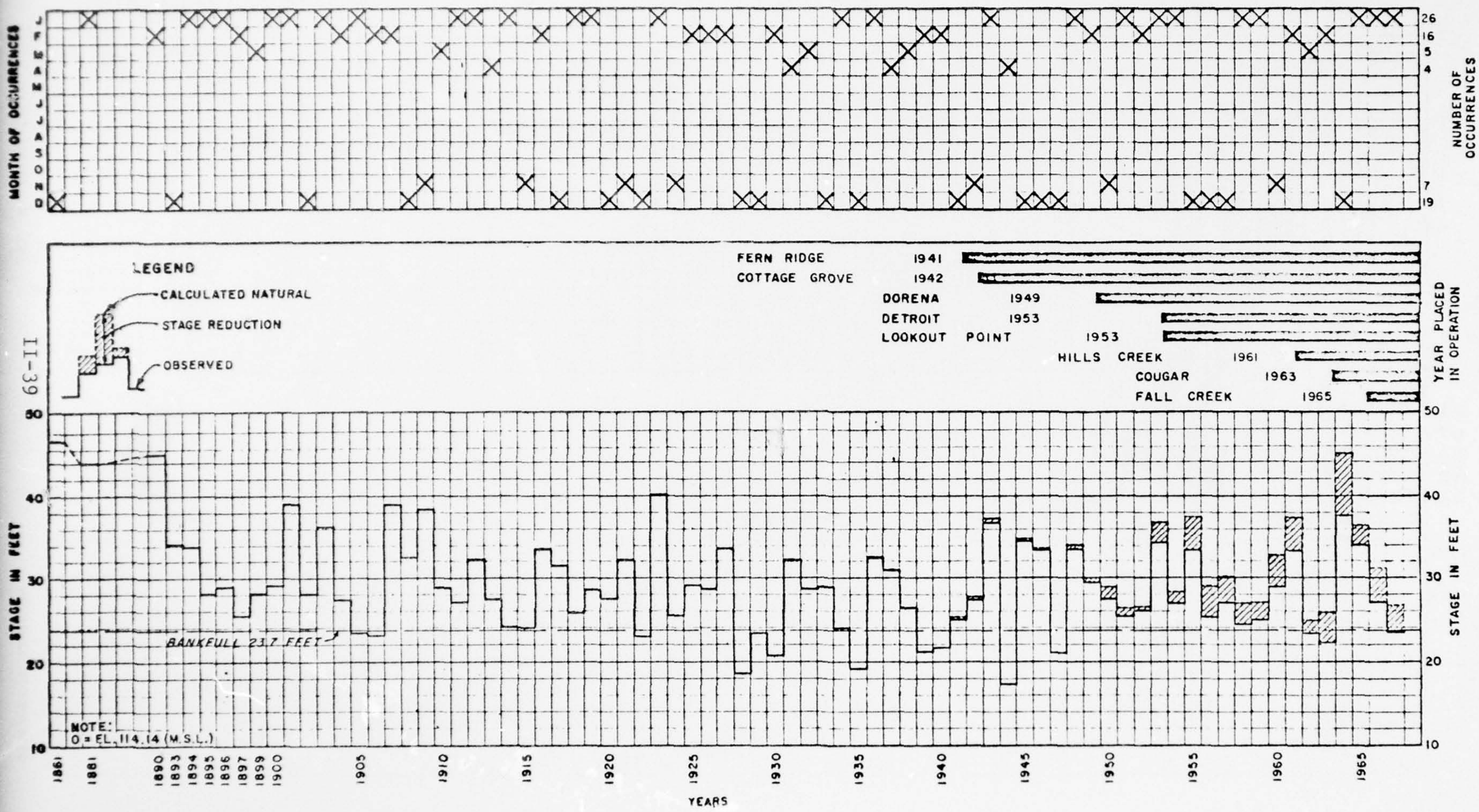
OREGON

NATURAL & OBSERVED HYDROGRAPHS
FLOOD OF DECEMBER 1964

1968

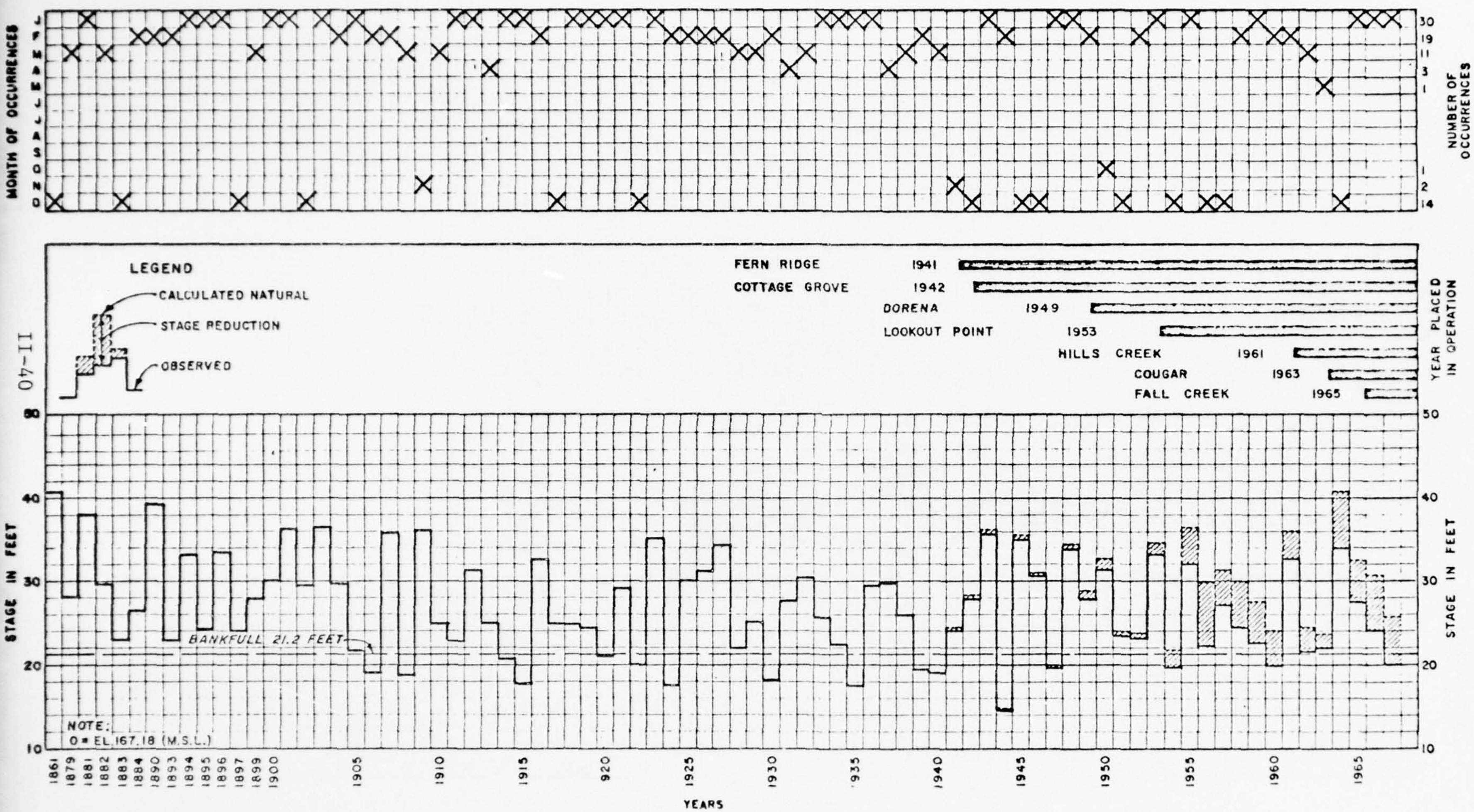
2

FIGURE II - 4A



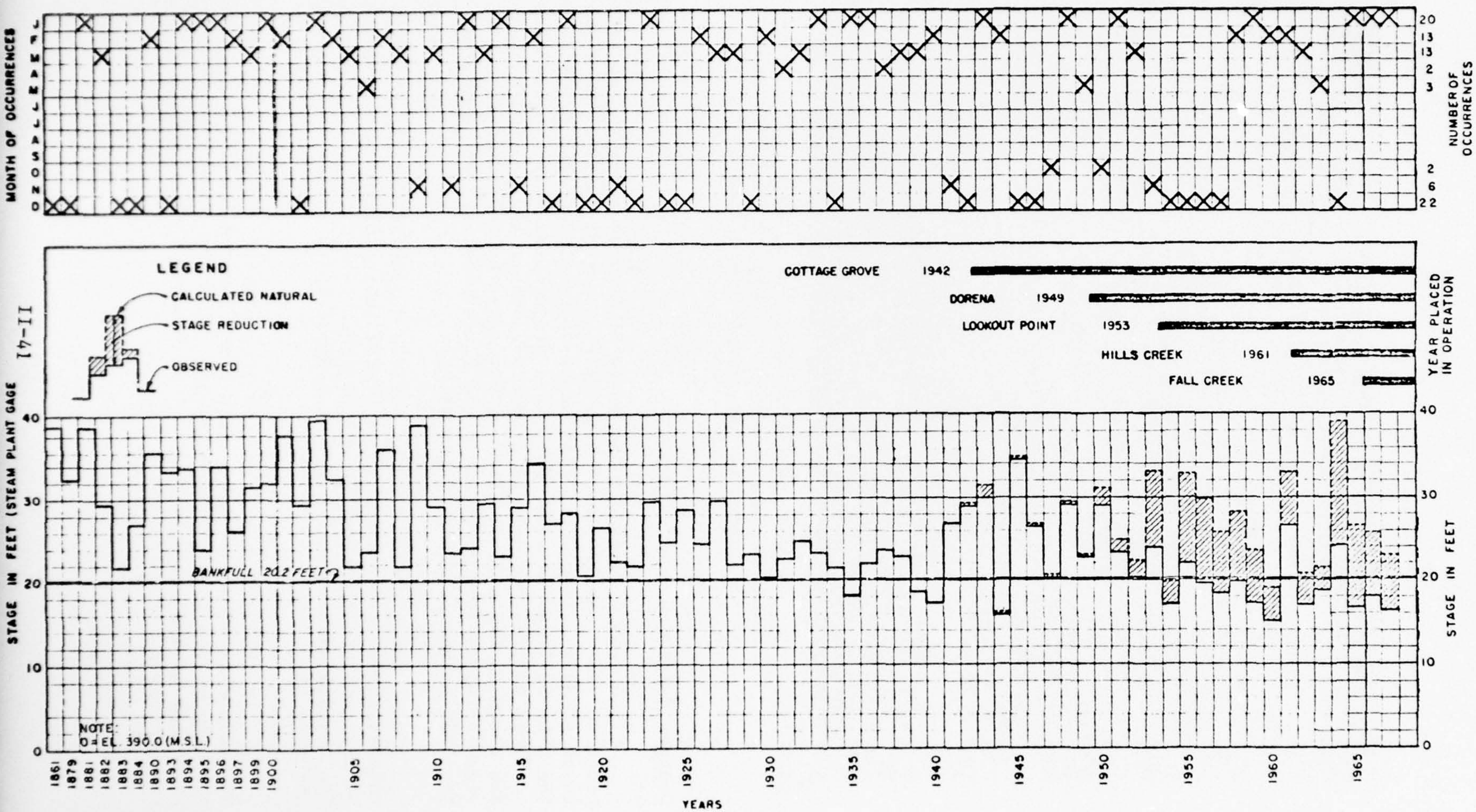
MAXIMUM ANNUAL STAGES - WILLAMETTE RIVER AT SALEM, OREGON

FIGURE II -- 4B



MAXIMUM ANNUAL STAGES - WILLAMETTE RIVER AT ALBANY, OREGON

FIGURE II - 4C



MAXIMUM ANNUAL STAGES - WILLAMETTE RIVER AT EUGENE, OREGON

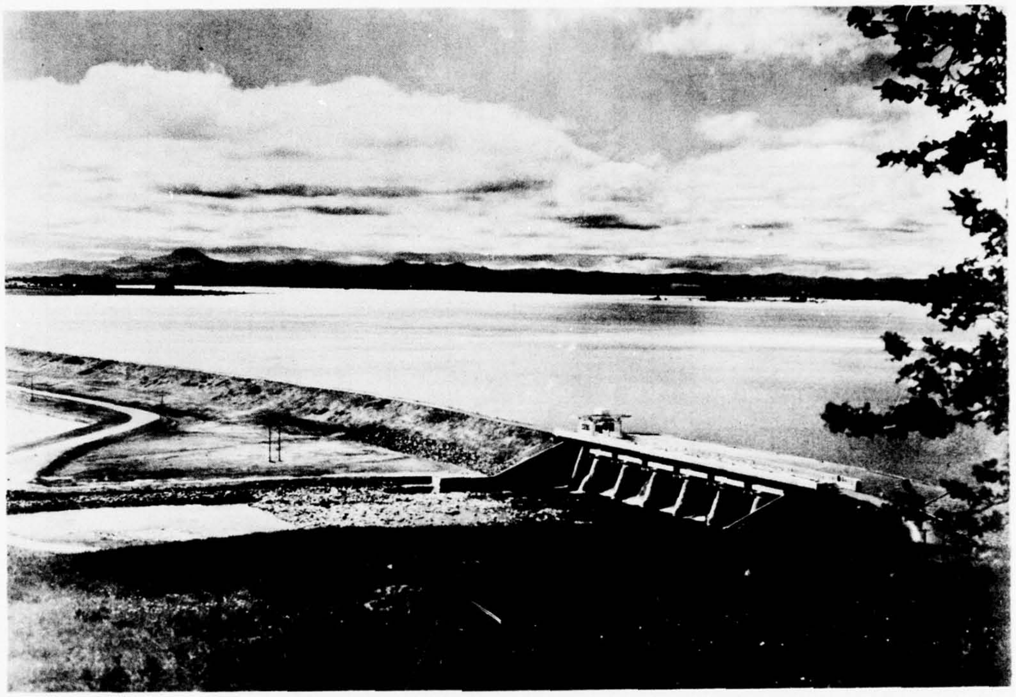


Photo II-19 Fern Ridge Reservoir, completed in 1941 by the Corps of Engineers, was the first multiple-purpose reservoir project built in Willamette Basin. (USCE Photo)

Damages Prevented

Flood damages prevented by Corps of Engineers dam and reservoir projects since completion of Fern Ridge Reservoir in 1941 have amounted to about $594 million, of which about $510 million were prevented during the 1964-65 flood season. Estimated project investment costs allocated to flood control and damages prevented, by dam and reservoir projects, are shown on Table II-9. Damages prevented by the bank protection and channel improvement works since the first revetment was completed in the 1930's are estimated at $18 million.

Flood damages prevented by Soil Conservation Service projects totaled about $4.9 million as of Fiscal Year 1965, of which about $4 million were prevented in the December 1964-January 1965 floods. The average annual flood prevention benefits to be expected are shown in Table II-10.

It is estimated that flood control benefits averaging $4,000 annually will accrue when Scoggins Creek Dam and Reservoir are constructed by the Bureau of Reclamation. The area to be benefited lies primarily in a 3-1/2 mile strip along Scoggins Creek immediately downstream from the damsite.

Table II-9

Accomplishments - Corps of Engineers dams and reservoirs
(Thousands of dollars at time of Occurrence)

Project & year placed in operation		Total thru FY 59	FY 60	FY 61	FY 62	FY 63	FY 64	FY 65	FY 66	FY 67	FY 68	Cumulative Total	Invest. Cost Alloc. to Flood Control
Fern Ridge	1941	6,552	114	2,115	775	797	1,711	39,147	1,666	115	93	53,085	3,553 1/
Cottage Grove	1942	9,332	39	2,259	1,159	223	2,027	16,641	1,055	43	7	32,775	1,519 1/
Dorena	1949	8,181	79	6,590	1,385	229	1,894	53,581	1,664	207	37	73,847	8,195 1/
Detroit and Big Cliff (reregulating)	1953	4,120	45	4,159	349	389	358	145,816	662	237	613	156,748	21,035 2/
Lookout Point and Dexter (reregulating)	1953	10,710	86	4,242	480	229	472	124,487	2,244	451	226	143,627	46,711 2/
Hills Creek	1961				270	131	151	70,793	1,128	275	120	72,868	26,488 2/
Cougar	1963						370	58,835	515	131	40	59,891	36,926 2/
Fall Creek	1965								588	175	72	835	13,696 1/
Green Peter	1966									55	209	264	29,517 2/3/
Foster	1967												
Blue River	1968										0	0	20,480 4/
Total		38,885	363	19,365	4,418	1,998	6,983	509,300	9,522	1,689	1,417	593,940	208,120

1/ *Total plant-in-service investment cost allocated to Flood Control to 30 June 1968.*
2/ *Estimated total project investment cost allocated to Flood Control.*
3/ *Includes Green Peter and Foster.*
4/ *Costs of record as of January 1969.*

Table II-10
Flood control benefits
RC&D and PL 83-566 (SCS) projects

Project	Average Annual Benefit	Benefited Area
Lynx Hollow	$ 32,100	1,000 ac. agr. land, City of Creswell, State Highway 231
Willakenzie	223,600	900 ac. agr. land, City of Springfield, Interstate Highway 5
Little Pudding River	75,200	2,000 ac. agr. land
Beaver Creek	17,400	1,000 ac. agr. land
Lower Amazon-Flat Creek	173,100	10,000 ac. agr. land, City of Junction City
Central Dist. Flood Protection	6,700	300 ac. agr. land
Total	$528,100	

Nonstructural Measures

Flood Plain Management Services

Information as to flood damage potential is being made available through programs by the Corps of Engineers, Soil Conservation Service, and Geological Survey at the request of, and in cooperation with, State and local governments. This program has been underway since 1960, and the information is made available to State and local governments and individuals. Lane County has used information developed under this program in its land use planning studies. No detailed estimate is available to show the extent to which land development control through zoning and other regulations has accomplished or will accomplish flood damage reduction. This subject is discussed further in Appendix M, Plan Formulation.

Watershed Management

The estimated cost of watershed management and timber harvest management practices on National Forests in Willamette Basin is about $8.5 million annually. Accomplishments of management practices, though real, cannot be easily measured. However, benefits from such practices, including flood damage reduction, are estimated to equal or exceed costs. Watershed management practices such as reducing the amount of debris from forest areas, removing flood deposited debris, etc., lessen the effects of flooding by minimizing erosion, smoothing out flood peaks, minimizing sedimentation and streambed aggradation, and reducing damages in other ways.

Flood Forecasting and Warning

Although precise data describing the benefits of the flood forecasting program are not available for Willamette Basin, nationwide Weather Bureau statistics show that about 10 percent of potential flood damages are prevented by flood warnings. A recent example of flood forecast utilization came on December 21, 1964, when timely recognition of the potential flood conditions in both the Willamette and lower Columbia Rivers permitted the reservoirs in Willamette Basin as well as Columbia Basin to be operated with optimum effect. During that flood, reservoir regulation reduced the stage in Eugene by about 15 feet and in the Portland harbor by about 4.6 feet.

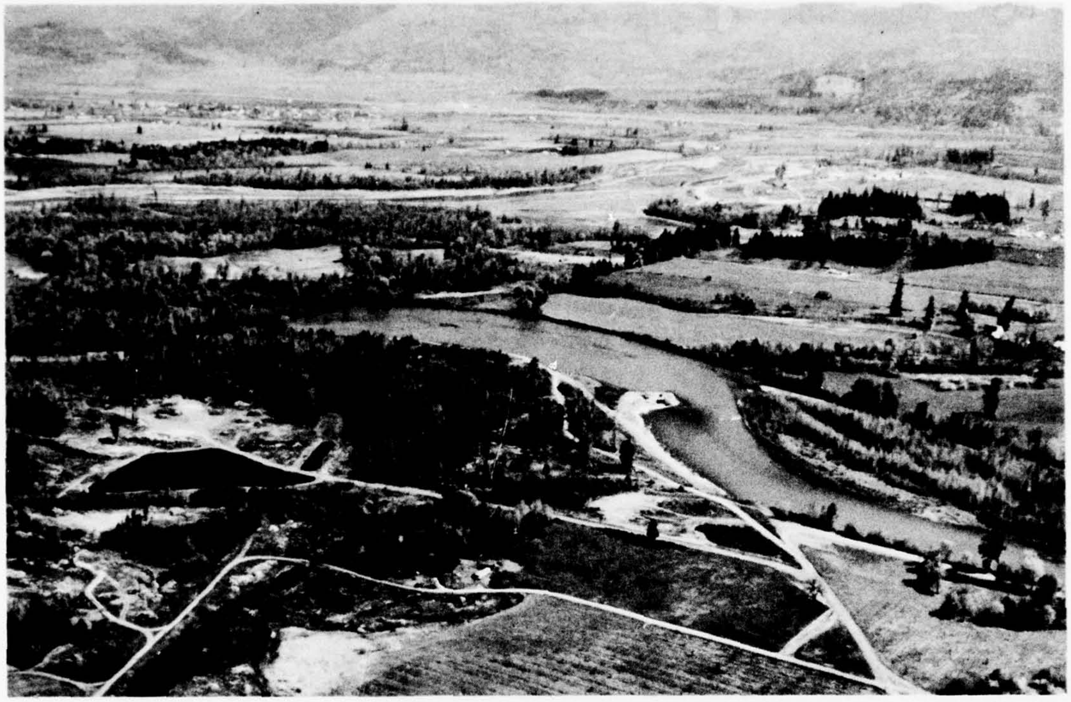


Photo II-20 Man has assumed the risk of using the flood plain, sometimes without taking cognizance of the disadvantages. (OSHD Photo)

Photo II-21 As population, development, and demands for land increase, man assumes even greater risks in his use of flood plain land. (OSHD Photo)

FUTURE DEMANDS

FUTURE DEMANDS

Flood runoff, erosion, debris-clogged streams, and inundation of lands are natural phenomena. Before the advent of settlement and economic development, the principal effect of past flood events was to reshape the Willamette Basin's topography and create the flood plain lands. Flood damages as such were not recognized because no damageable improvements existed on the flood plain.

Significant and measurable flood damages are a sequel to man's use of the flood plain. As settlement and development of Willamette Basin took place, agriculture was established and improvements were constructed. Much of this development took place in the flood plain because of the advantages offered. These lands and improvements then assumed considerable monetary value.

In general, man has assumed the risks of using the flood plain taking cognizance of the advantages of such a location. The risks and disadvantages, however, are seldom accurately assessed, because the general public has only limited knowledge of where, how often, and how severe a flood might be. Consequently, occupants and users of the flood plain are often exposed to unexpected danger and subject to greater-than-expected property damage.

As population, development, and demands for land increase, the amount of desirable land becomes smaller, and use of the flood plains becomes more intensive. Under those conditions, the value of land and improvements subject to flood damage compounds with the passage of time. Thus, the future need and demand for protection from flood damage can be expected to increase rapidly if corrective actions are not taken. The following outlines the basis for, and presents projections of, such future demands. These projected demands are based on the population and development projections in Appendix C - Economic Base.

PROJECTED FLOOD PLAIN DEVELOPMENT

With uncontrolled development on the flood plain, damage potential increases rapidly in response to population growth, resource development, intensified land use, and related factors. The risk of damages resulting from these factors can be reduced by providing structural and nonstructural measures. Decisions as to the nature and relative magnitude of appropriate flood control elements of a basin plan, however, are a part of the plan formulation study, discussed in Appendix M.

Flood damages to lands and improvements fall into three major categories: (1) agricultural, (2) industrial, and (3) community. These are defined as follows:

1. Agricultural - Includes all agricultural lands, damageable improvements thereon, and their uses.

2. Industrial - Includes damageable improvements and lands related to all mining and manufacturing and their activities. Manufacturing includes both the processing of raw materials into fabricated materials and the conversion of fabricated inputs into finished products. Principal examples in Willamette Basin are sand-and-gravel operations; food processing plants; lumber, plywood, pulp and paper mills; and chemical, primary metal, and light manufacturing plants.

3. Community - Includes all damageable improvements, associated lands, and uses not defined in (1) and (2). Principal examples are residential areas, warehouses, residentiary business establishments, railroads, highways, bridges, and all other transportation facilities, public properties, and various public utilities.

The damageable value per unit area is greatest for industrial, followed by community, then agriculture. Moreover, the future flood damage potential in the respective categories will increase unequally, because each is dependent upon a unique set of growth factors. Potential damages in agricultural areas will increase largely in response to agricultural economic growth, those in industrial areas in response to industrial development. Potential damages to community improvements will increase largely in response to population growth and attendant development.

PROJECTED DAMAGE REDUCTION NEEDS

The projected needs for flood damage reduction are expressed in both monetary and physical terms; that is, in average annual flood damages, and in the flood flow and stage reductions needed to prevent damage. In general, average annual monetary losses are more expressive because they reflect both the amount of damage and the progressive increases of damage potential over time. Needed flow and stage reductions, on the other hand, are about the same now as would be projected for some future date; the principal change over time is in the degree of need for such reductions. Those reduction needs, however, provide a description of physical conditions, and can be converted to needs for acre-feet of flood control storage. Also, the degree of needs for stage reduction can be shown by stage-damage relationships.

AVERAGE ANNUAL MONETARY DAMAGES

The projected average annual residual flood damages for Willamette Basin are those expected to occur after all existing and authorized projects and programs are implemented. The projected damages are summarized in Table III-1 and shown in Figure III-1. Detailed projections are shown in Addendum B.

Table III-1
Projected average annual residual flood damages

Year	Agricultural	Community	Industrial	Total
1965	$ 2,400,000	$ 2,800,000	$ 200,000	$ 5,400,000
1980	2,900,000	3,800,000	400,000	7,100,000
2000	3,700,000	6,400,000	1,000,000	11,100,000
2020	5,100,000	12,600,000	2,600,000	20,300,000

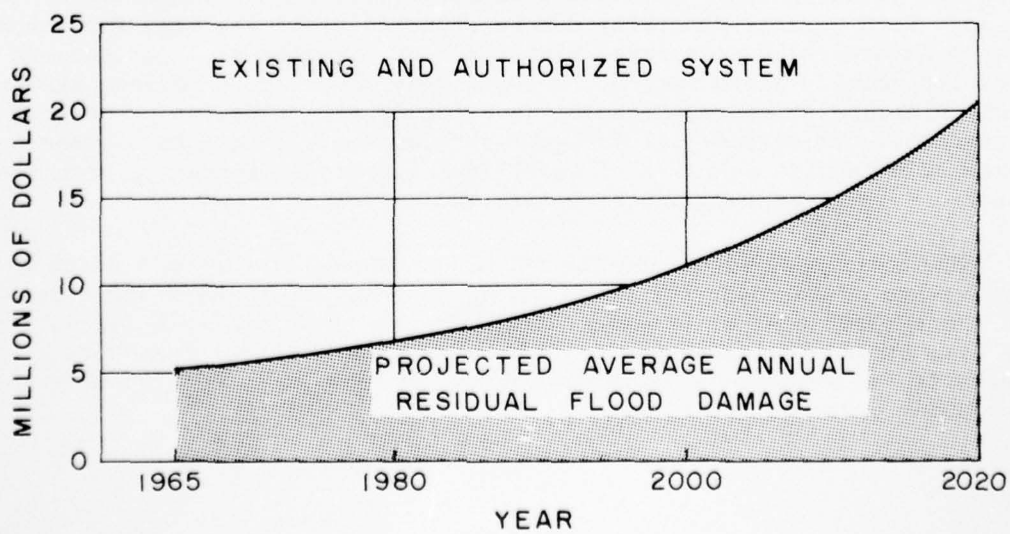


Figure III-1 Projected average annual residual flood damages.

Photo III-1 Portland's lower east-side warehouse district was inundated with several feet of water during the December 1964 flood. (USCE Photo)

REDUCTION OF FLOOD FLOWS AND STAGES

The existing and authorized reservoir projects, when operated according to plan, are capable of containing most floods at the project sites and reducing flows to bankfull capacity for some distance downstream. Such effects generally can be expected to be realized for floods up to a natural peak discharge which could be expected to occur once in about 100 years. There remain, however, many miles of the stream system in which either no storage control is effected or the degree of control is inadequate to satisfy all damage reduction needs. In general, the degree of need for reduction of peak flows and stages increases with the distance downstream from project sites and headwater areas.

The additional flood control needs are those which remain after the base system of 18 reservoir projects is in operation. Those projects and their flood control storage capability are shown in Table III-2. The base system includes existing and authorized Corps of Engineers reservoirs plus those projects considered as being assured of construction under other authorities.

Table III-2
Existing, authorized and assured flood control reservoir projects

Reservoir	Stream	Flood Control Storage (acre-feet)
	EXISTING	
Fern Ridge	Long Tom R.	110,000
Cottage Grove	Coast Fork Will. R.	30,000
Dorena	Row River	70,500
Detroit	N. Santiam River	300,000
Lookout Point	Mid. Fork Will. R.	337,000
Hills Creek	Mid. Fork Will. R.	200,000
Cougar	S. Fork McKenzie R.	155,000
Fall Creek	Fall Creek	115,000
Green Peter	Mid. Santiam R.	270,000
Foster	S. Santiam River	30,000
Blue River	Blue River	85,000
	AUTHORIZED	
Holley	Calapooia River	90,000
Cascadia	S. Santiam River	145,000
Gate Creek	Gate Creek	50,000
Scoggins	Scoggins Creek	Incidental
	ASSURED	
Gorge	Mill Creek	25,000
McKay Creek	McKay Creek	7,000
Rock Creek	Rock Creek	5,700

CONTAINMENT OF FLOOD FLOWS

Flood flows can be contained within channels by enlarging, deepening and/or straightening the existing channels, or by construction of levees and flood walls along the banks. A flood wall along the east bank of Willamette River in downtown Portland, similar to that on the west bank, could have prevented considerable flooding during the 1964 flood (see Photo III-1).

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THE WILLAMETTE BASIN COMPREHENSIVE STUDY OF WATER AND RELATED L--ETC(U)
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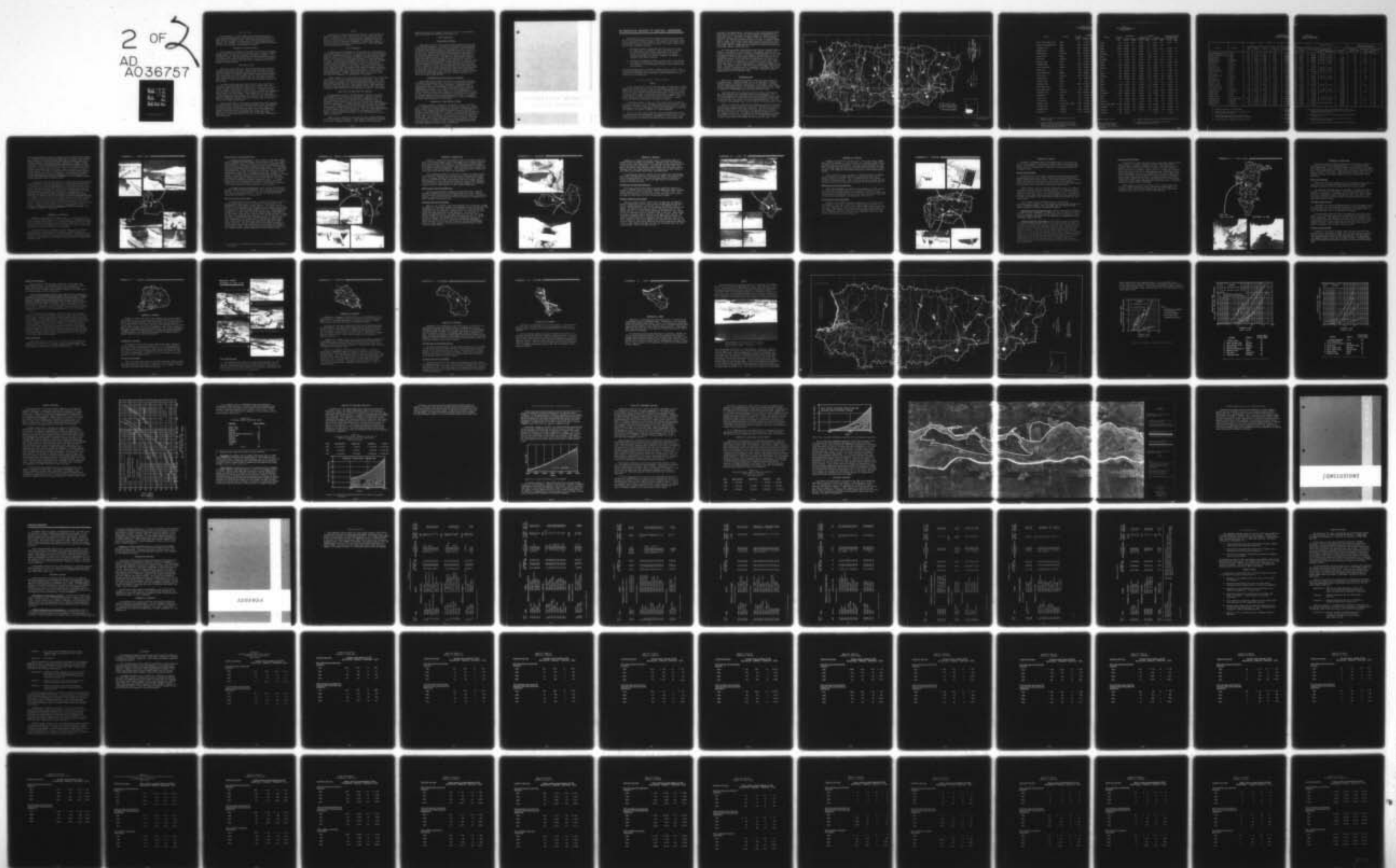


P R O B L E M S

The formulation of a plan which will provide satisfaction of flood control needs involves consideration of problems in addition to those created by damaging floods. Those additional problems are, at least in part, peculiar to consideration of flood-damage prevention measures. The problems of implementing flood damage reduction measures are physical, cultural, institutional, and legal.

SHORTAGE OF SUITABLE DAMSITES

Flood control in Willamette Basin cannot be achieved by reservoir storage alone because there are not enough suitable, properly located storage sites. At some sites, geologic conditions preclude the construction of dams. Several sites with good storage capability are not so located as to control sufficient runoff. In other cases, improvements within the reservoir area and/or local opposition rule out an otherwise feasible project.

CONFLICTS OF USES

Conflicts of both water and land uses complicate the problem of achieving flood damage reduction. Flood control operation of multipurpose reservoirs is generally compatible with other uses, because the flood season in Willamette Basin normally occurs during the winter rainy period when most other demands are low. The lands occupied by some storage sites may have unique values for other public uses and these should be weighed against the flood control benefits provided by each project.

The need to hold reservoirs down for flood control conflicts at times with recreational and other water uses. In some cases, the reservoirs cannot be completely filled for other uses after the flood season, because spring runoff is insufficient. Although infrequent, such occurrences can adversely affect recreation, irrigation, navigation, water quality, and water supply. Power demands conflict with flood control operation to some extent in that reservoirs are drawn down to provide storage space and available head for generation is thereby lost. While the reservoirs are being evacuated, however, part of the water can be run through the generators.

Channel improvement in some cases is detrimental to fish resources and sport fishing. During the construction phase, channel improvement may adversely affect water quality locally, for a short time. While no serious problems are anticipated, construction and maintenance of channel improvement facilities, revetments, levees, and other works, may prove to be partially incompatible with recreational usage. Resolution of the various conflicts of uses is discussed in Appendix M - Plan Formulation.

LEVEES

Construction of levees presents some problems. Land required for levees is removed from other uses, and use of land riverward of the levee is restricted. Also, a flood in excess of design capacity can result in levee failure or in overtopping and inundation of the protected area with the attendant possibility of catastrophic damages. If levees are used for protection of inhabited areas, a very high degree of protection should be provided.

LOCAL COOPERATION

A largely unresolved problem is the provision of an effective and satisfactory means of non-Federal cost sharing in flood control measures. Under the 1936 Flood Control Act, as amended, and under numerous Federal policies, various local cooperation measures, sometimes including cost sharing, are required for local protection works. A highly desirable solution, from the Federal standpoint, would be for the State of Oregon to provide such cooperation; however, the State has found that the required assurances cannot be furnished because of Constitutional restrictions on the extension of its credit. In effect, in the case of local protective works, this requires the Federal government to obtain local cooperation from a multitude of small groups. In many cases, such groups either are unwilling or financially unable to enter into the necessary agreement. On some constructed works, local entities have not fulfilled commitments for maintenance as stipulated.

Another problem is that some local flood protection works constructed under early Acts did not require non-Federal maintenance. It is somewhat difficult to explain to interested landowners, particularly those with adjacent properties, that local funding and maintenance is now required for identical projects. Some urgently needed, authorized bank protection works requiring local cooperation have not been constructed because the local groups were either unwilling or unable to participate.

FLOOD PLAIN USE REGULATION AND EDUCATION

The appropriate extent of zoning and other regulation to reduce flood damages in a particular area is related to physical, economic, and political factors, and may be expected to change with time. If flood elevation is used as a criterion, a basic problem will be to determine to what elevation above the river special flood regulations should be implemented. At higher elevations, inundation is so infrequent that it is not reasonable or economical to apply the restrictions which are necessary at lower elevations. An even more difficult task may be to enforce flood plain zoning regulations. This is a local responsibility and the officials involved are subject to the demands of the local people. A more detailed discussion of flood plain management is presented in Section IV.

There is also a problem of educating the public through dissemination of flood-hazard information. Even though information is furnished by a variety of means and media, a large segment of the population

remains uninformed with respect to both the location of flood-hazard areas and the need for regulating flood plain use.

FLOOD FORECASTING

Forecasting Procedures

Improvements could be made to both the data-gathering system and to forecasting techniques. Although the existing hydro-meteorological system serving Willamette Basin is fairly effective, more information on snowpack depth and associated air temperatures and more rapid collection of all hydro-meteorological data would improve the accuracy of the forecasts. However, the greatest opportunity for improvement is that of predicting accurately the amount of rainfall which would be produced by oncoming storms. With more data and improved techniques, runoff forecasts could be improved so that existing flood control reservoirs could be operated somewhat more effectively. Fairly accurate stage forecasts can be developed for downstream areas because most of the flood-producing rainfall has occurred long before the flood peak arrives. However, the flood control reservoirs are located much closer to the source of the runoff, and plans for regulation of the reservoirs are made even before the first flood flow occurs. The prediction of storm rainfall has proven to be a difficult problem to solve, but hopes are held for improvement through the use of weather satellites and other technological developments.

Dissemination and Utilization of Forecasts

Even though flood forecast information is widely and effectively distributed in Willamette Basin, it is up to the individual occupants of the flood plain to act on this information. Sometimes people or organizations fail to take advantage of this information because of complacency or unbelief. To be sure, a difficult decision faces the individual whose property may or may not be flooded depending on a slight variation in water level; however, it is normally better to play it safe. One other problem here involved is the difficulty in applying the forecast information to an individual piece of land. Flood plain information reports currently being prepared by the Corps of Engineers, and other Federal agencies will be helpful.

EVACUATION OF FLOOD CONTROL STORAGE

Existing reservoirs, in general, are sized to control a 100-year flood. Because more than one major flood can occur in any year, evacuation to regain full storage capability is essential following each flood. Because of the rapidity with which flood peaks can recur, evacuation should be accomplished within 10 to 15 days. In many reaches the existing channel does not have capacity to contain the resulting total evacuation period flows. As a consequence, low-lying areas often are inundated for several days, and access to many areas is blocked or impeded. The need is for measures to provide increased capacity consistent with required evacuation flows, for whatever level of storage development may result from plan formulation studies, shown in Appendix M.

ALTERNATIVE MEANS TO SATISFY DEMANDS

Flood damages may be reduced by keeping floodwaters away from man and his works, by keeping man and his works away from flood-prone areas, or by a combination of those measures. Accordingly, flood damage reduction measures fall into two general categories, structural measures and nonstructural management measures:

1. Structural measures include dams and reservoirs for storage and regulation of floodwaters; levees and related structures to confine floodflows; channel stabilization by bank protection, drift barriers, and related works; and channel capacity improvement by clearing, snagging, realinement, enlargement, and similar measures.

2. Nonstructural management measures include, but are not limited to, zoning to regulate use of flood-prone areas, allowing only those uses with low flood-damage potential, and flood-proofing of structures.

Structural measures may be effected at Federal, State, or local level. Nonstructural management measures are a non-Federal prerogative. Various structural and nonstructural flood-damage reduction measures are discussed in the following text.

STRUCTURAL MEASURES

STORAGE

Storage is generally the most effective means for reduction of flood damages if suitable reservoir sites are available at appropriate locations. Unlike many other parts of the country, where flooding may occur at any time of the year, Willamette Basin experiences major floods only during the winter rainy season. This permits joint usage of storage space, for flood control in winter and conservation purposes in summer. Thus, the use of storage for flood control often makes it possible to realize needed but otherwise unobtainable conservation benefits.

In Willamette Basin, storage for flood control can be obtained by developing new sites, or by enlarging existing storage reservoirs. Determination of the best method, and consideration and resolution of problems pertaining to both new developments and possible enlargement of existing developments, is covered in Appendix M - Plan Formulation.

Most of the better large reservoir sites in Willamette Basin have been developed for multiple-purpose use including flood control, or their construction has been precluded by improvements in the reservoir area. "Large reservoir" is arbitrarily defined as one with more than 10,000

acre-feet of storage capacity. Locations of those remaining undeveloped sites which now appear to have the best potential for development are shown on Map IV-1. The amount of storage needed for complete control of a 100-year flood at those sites is shown in Table A-1 in the Addendum. Control of the 100-year flood was selected as a basis of analysis rather than as a goal. Each project would require specific evaluation of flood control requirements; projects protecting urban and industrial developments might require a higher degree of protection; those protecting rural areas might require considerably less.

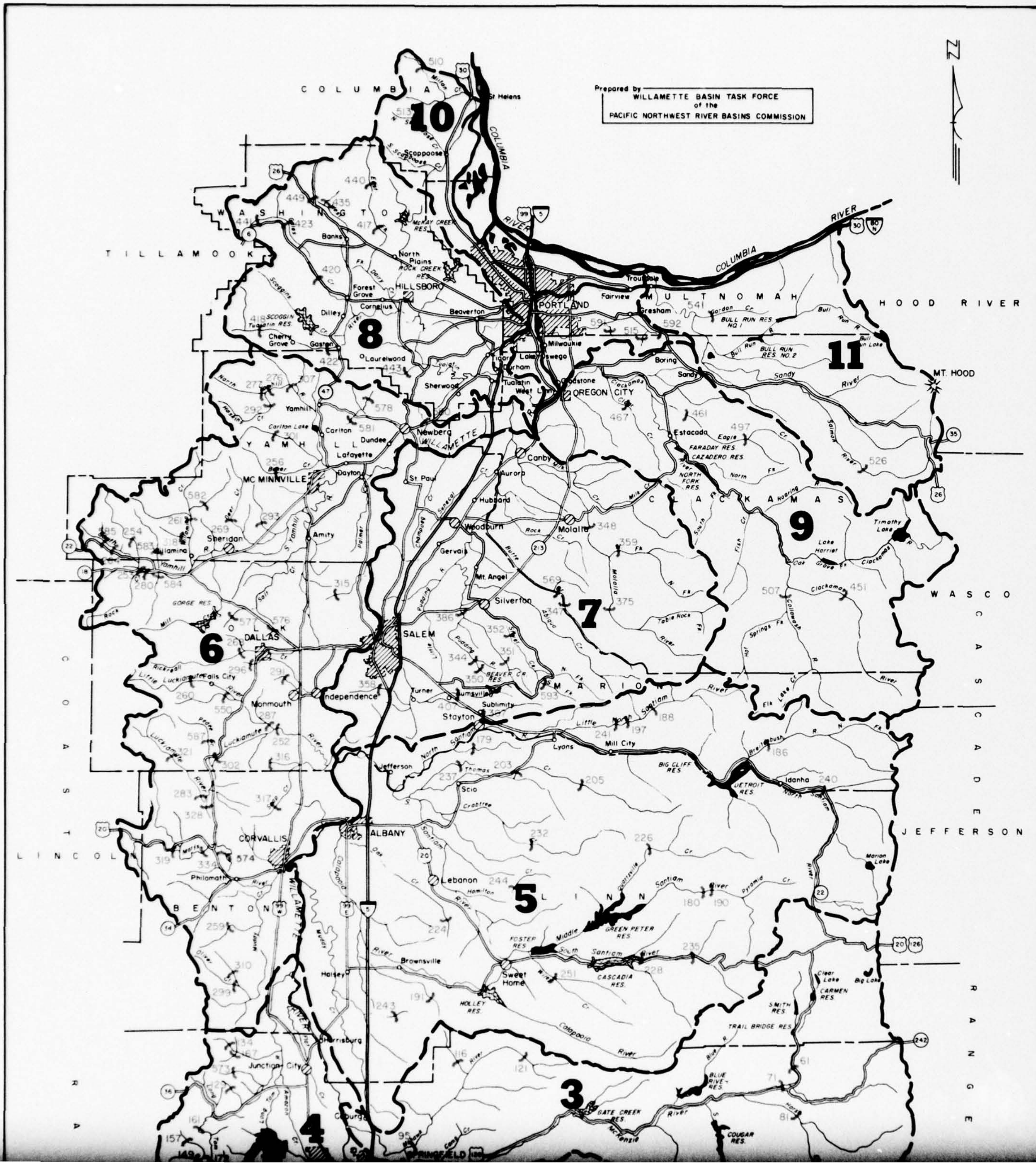
The following subbasin presentations show the total storage capacity needed, in the absence of other measures, for complete control at the reservoir site and for effective control at downstream stations; the total existing and assured storage in the subbasin; the potential, if any, for enlargement of existing and assured projects; and the potential for new storage development, all on the basis of requirements for control of a 100-year flood as an illustration of the amount of flood control need. "Effective control" is that degree of control required to reduce flood stage sufficiently to prevent substantially all significant damage in the reach. The 100-year flood is used rather than the December 1964 flood in order to provide a uniform basis for comparison; the December 1964 flood varied somewhat in magnitude from place to place although its general magnitude was that of a 100-year flood.

Willamette River

Most of the flood-damage potential in the basin lies adjacent to Willamette River. However, storage can only be provided on tributary streams, because no feasible sites exist on the Willamette. Moreover, even if enough reservoirs were constructed to effectively control floods in those few subbasins where it is possible, there would still be a need for additional flood-damage reduction along Willamette River.

In December 1964, the reservoirs and other works in operation at that time prevented more than $500 million in flood damages. Still, $70 million damages were sustained, mostly along Willamette River. Some of those damages can be prevented by providing storage on uncontrolled tributaries, but other means - structural and nonstructural - also will be needed to bring damages down to an acceptable level during major floods.

Table IV-1 shows the flood peak flow regulation required, and Table IV-2 shows the storage required to control the 100-year flood at control points along Willamette River and tributaries. The "Total required at station" (Table IV-2) is the amount of storage necessary to control the 100-year flood to the flow regulation requirement (Table IV-1) at the respective stations. For example, the storage requirement at Eugene of 612,000 acre-feet would regulate the flow to 40,000 cubic-feet-per-second at which stage flood damages would be relatively minor. The



Prepared by
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LINCOLN
JEFFERSON
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CASCADE RANGE
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MT. HOOD
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SALEM
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CORVALLIS
HILLSBORO
DALLAS
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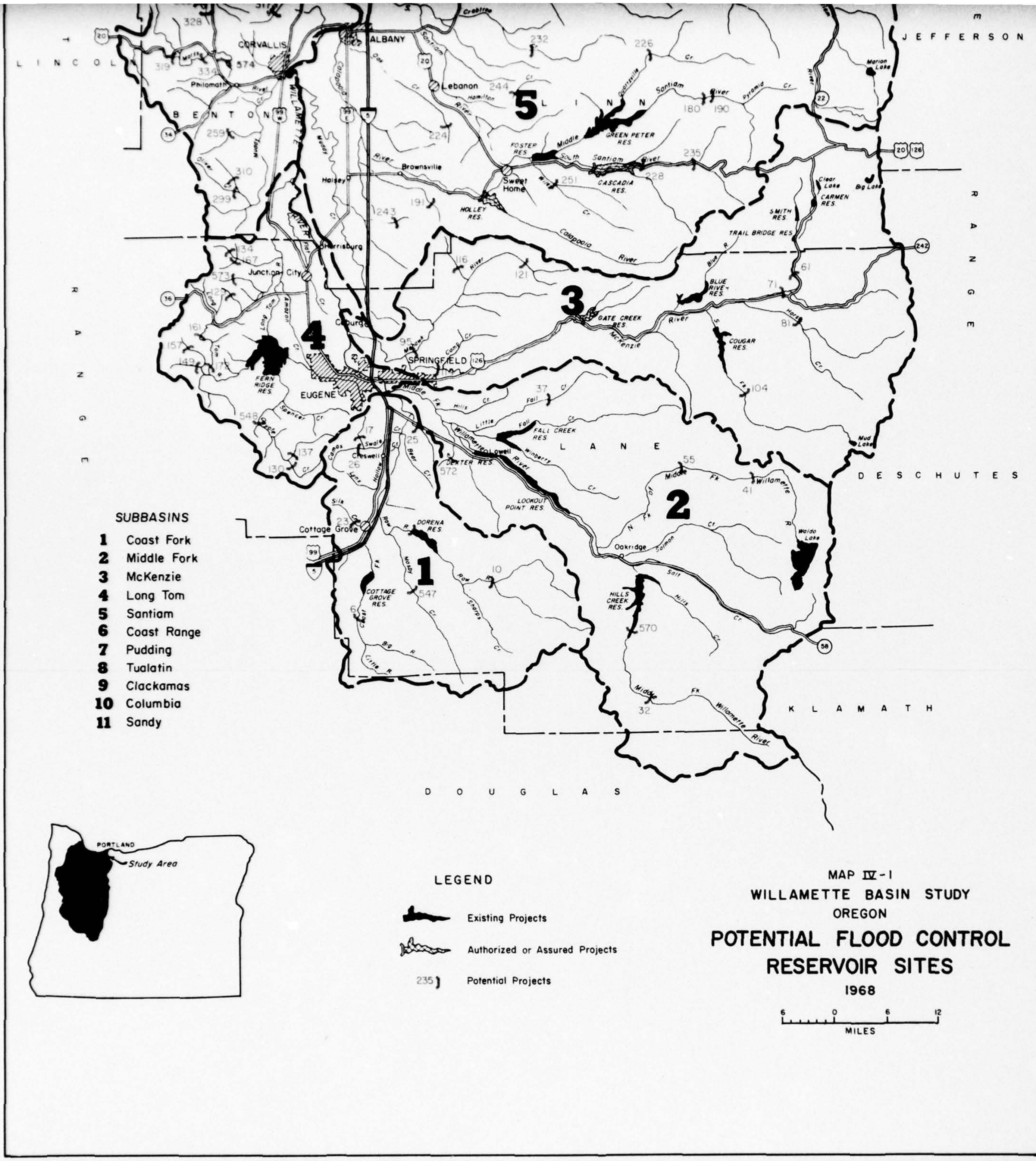

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Table IV-1
Flood peak regulation d
(100-year flood)

Stream	Station	Drainage area sq. mi.	Unregulat Discharge (c.f.s.)	St (f
Coast Fork Willamette River	Goshen	642	74,500	2
Middle Fork Willamette River	Jasper	1,340	142,000	2
Willamette River	Eugene	2,030	188,000	3
McKenzie River	Coburg	1,337	120,000	2
Willamette River	Harrisburg	3,420	305,000	2
Long Tom River	Monroe	391	30,800	1
Marys River	Philomath	159	14,500	2
Calapooia River	Albany	372	45,000	2
Willamette River	Albany	4,840	320,000	4
South Santiam River	Waterloo	640	98,000	2
Thomas Creek	Scio	109	20,000	2
North Santiam River	Mehama	655	108,000	1
Santiam River	Jefferson	1,790	245,000	2
Luckiamute River	Suver	240	35,000	3
Rickreall Creek	Dallas	27	8,100	
Willamette River	Salem	7,280	475,000	4
North Yamhill River	Pike	67	11,000	1
South Yamhill River	Whiteson	502	55,000	4
Willamette River	Wilsonville	8,400	490,000	10
Pudding River	Aurora	479	30,000	3
Molalla River	Canby	323	42,000	1
Tualatin River	West Linn	706	31,500	2
Willamette River	Willam. Falls (Upper)	10,100	540,000	2
Clackamas River	Clackamas	936	120,000	2
Willamette River	Portland	11,200	575,000	3
Sandy River	Troutdale	502	90,000	

1/ Stages are based on rating tables in use February 1969.

2/ Corps of Engineers existing and authorized projects and projects assured under other authorities have the capability of regulation to the flows and stages shown.

Table IV-1
Flood peak regulation data
(100-year flood)

Station	Drainage area sq. mi.	Unregulated Discharge (c.f.s.)	Unregulated Stage 1/ (feet)	Regulated Capability 2/ Discharge (c.f.s.)	Regulated Capability 2/ Stage 1/ (feet)	Regulated Goal 3/ Discharge (c.f.s.)	Regulated Goal 3/ Stage 1/ (feet)	Additional Reduction to accomplish goal Discharge (c.f.s.)	Additional Reduction to accomplish goal Stage (feet)
Goshen	642	74,500	20.0	36,000	17.5	12,000	11.7	24,000	5.8
Jasper	1,340	142,000	22.5	20,000	9.3	20,000	9.3	-	-
Eugene	2,030	188,000	38.5	60,000	24.1	40,000	20.2	20,000	3.9
Coburg	1,337	120,000	22.0	70,000	15.9	24,000	8.7	46,000	7.2
Harrisburg	3,420	305,000	25.2	110,000	16.2	45,000	9.5	65,000	6.7
Monroe	391	30,800	11.7	13,000	8.0 4/	6,000	8.6	7,000	-
Philomath	159	14,500	20.8	14,500	20.8	3,000	16.6	11,500	4.2
Albany	372	45,000	23.0	33,000	22.0	5,500	14.0	27,500	8.0
Albany	4,840	320,000	40.2	150,000	31.7	60,000	19.2	90,000	12.5
Waterloo	640	98,000	24.9	22,000	10.8	18,000	9.7	4,000	1.1
Scio	109	20,000	20.2	20,000	20.2	3,000	7.6	17,000	12.6
Mehama	655	108,000	18.0	53,000	13.0	17,000	8.0	36,000	5.0
Jefferson	1,790	245,000	25.8	135,000	22.0	35,000	13.2	100,000	8.8
Suver	240	35,000	34.9	35,000	34.9	5,000	24.9	30,000	10.3
Dallas	27	8,100	9.3	8,100	9.3	1,300	4.7	6,800	4.6
Salem	7,280	475,000	46.5	230,000	32.5	100,000	21.3	130,000	11.2
Pike	67	11,000	13.4	11,000	13.4	3,000	7.0	8,000	6.4
Whiteson	502	55,000	48.5	49,000	47.5	13,000	37.5	36,000	10.0
Wilsonville	8,400	490,000	104.0	233,000	85.6	115,000	72.5	118,000	13.1
Aurora	479	30,000	30.2	30,000	30.2	5,000	20.1	25,000	10.1
Canby	323	42,000	16.5	42,000	16.5	12,000	9.8	30,000	6.7
West Linn	706	31,500	20.0	31,500	20.0	6,000	9.4	25,500	10.6
Willam. Falls (Upper)	10,100	540,000	23.5	312,000	17.9	140,000	11.5	172,000	6.4
Clackamas	936	120,000	27.0	120,000	27.0	22,000	9.8	98,000	17.2
Portland	11,200	575,000	34.0	365,000	27.0	200,000	18.0	165,000	9.0
Troutdale	502	90,000	-	-	-	20,000	-	70,000	-

rating tables in use

xisting and authorized
s assured under other
capability of regulation
ges shown.

3/ Bankfull capacity with minor channel improvements.

4/ Stage based on natural channel conditions assuming failure of levees.

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Table IV-2
Storage requirements
control of 100-year

Stream	Station	Drainage area sq. mi.	Bankfull capacity c.f.s 1/	Regulation goal c.f.s. 2/	Channel capacity to evac. full reservoir 3/ c.f.s.	Total requ at station
Coast Fork Willamette River	Goshen	642	9,000	12,000	15,000	194,000
Middle Fork Willamette River	Jasper	1,340	16,000	20,000	35,000	568,000
Willamette River	Eugene	2,030	40,000	40,000	50,000	612,000
McKenzie River	Coburg	1,337	23,000	24,000	35,000	600,000
Willamette River	Harrisburg	3,420	40,000	45,000	85,000	1,300,000
Long Tom River	Monroe	391	5,400	6,000	9,000	143,000
Marys River	Philomath	159	2,900	3,000	4,500	50,000
Calapooia River	Albany	372	5,500	5,500	10,000	130,000
Willamette River	Albany	4,840	55,000	60,000	105,000	1,710,000
South Santiam River	Waterloo	640	18,000	18,000	23,000	400,000
Thomas Creek	Scio	109	3,000	3,000	3,000	15,000
North Santiam River	Mehama	655	17,000	17,000	22,000	315,000
Santiam River	Jefferson	1,790	32,000	35,000	50,000	800,000
Luckiamute River	Suver	240	5,000	5,000	7,000	105,000
Rickreall Creek	Dallas	27	1,000	1,300	1,700	10,000
Willamette River	Salem	7,280	70,000	100,000	160,000	2,500,000
North Yamhill River	Pike	67	2,500	3,000	3,000	17,000
South Yamhill River	Whiteson	502	11,000	13,000	13,000	145,000
Willamette River	Wilsonville	8,400	100,000	115,000	175,000	3,338,000
Pudding River	Aurora	479	5,000	5,000	11,500	150,000
Molalla River	Canby	323	9,000	12,000	12,000	75,000
Tualatin River	West Linn	706	5,500	6,000	14,000	294,000
Willamette River	Will Falls (Upper)	10,100	140,000	140,000	210,000	3,700,000
Clackamas River	Clackamas	936	20,000	22,000	22,000	305,000
Willamette River	Portland	11,200	200,000	200,000	190,000	2,750,000
Sandy River	Troutdale	502	20,000	20,000	20,000	200,000

1/ *Bankfull capacity as of March 1969.*

2/ *Regulation goal is the channel capacity with minor channel improvements.*

3/ *Channel capacity required to evacuate full reservoirs, existing and authorized in 10-days.*

4/ *Storage needed to accomplish regulation goal.*

5/ *Corps o projec of regu*

6/ *Effecti at upst*

7/ *Assumin control*

8/ *Storag*

Table IV-2
Storage requirements for control of 100-year flood

Channel capacity to evac. full reservoir 3/ c.f.s.	Storage in acre-feet: Total required at station 4/	Existing upstream from station 5/: Actual	Existing upstream from station 5/: Effective	6/ New commitment required	Runoff control in terms of drainage area (square miles): Required for control to regulation goal 7/	Upstream from existing projects 5/	Additional area required for control
15,000	194,000	100,500	95,500	98,500	539	369	170
35,000	568,000	652,000	590,000	-	1,151	1,175	-
50,000	**612,000**	752,500	600,000	12,000	1,595	1,544	51
35,000	600,000	290,000	245,000	355,000	1,070	346	724
85,000	1,300,000	1,042,500	890,000	410,000	2,914	1,890	1,024
9,000	143,000	110,000	104,500	38,500	315	275	40
4,500	50,000	-	-	50,000	126	-	126
10,000	130,000	90,000	76,000	54,000	327	105	222
105,000	1,710,000	1,242,500	1,050,000	660,000	3,931	2,270	1,661
23,000	400,000 8/	445,000	380,000	20,000	522	494	28
3,000	15,000	-	-	15,000	93	-	93
22,000	315,000	300,000	255,000	60,000	552	438	114
50,000	800,000	745,000	595,000	205,000	1,535	932	603
7,000	105,000	-	-	105,000	204	-	204
1,700	10,000	-	-	10,000	23	-	23
160,000	2,500,000	1,987,500	1,780,000	720,000	5,742	3,202	2,540
3,000	17,000	-	-	17,000	49	-	49
13,000	145,000	25,000	21,000	124,000	384	31	353
175,000	3,338,000	2,012,500	1,815,000	1,523,000	6,417	3,233	3,184
11,500	150,000	-	-	150,000	399	-	399
12,000	75,000	-	-	75,000	231	-	231
14,000	294,000	12,700	12,700	281,300	571	44	527
210,000	3,700,000	2,025,200	1,850,000	1,850,000	7,458	3,277	4,181
22,000	305,000	-	-	305,000	764	-	764
190,000	2,750,000	2,025,200	1,850,200	900,000	6,500	3,277	3,223
20,000	200,000	-	-	200,000	387	-	387

5/ *Corps of Engineers existing and authorized projects and projects assured under other authorities have the capability of regulation to flows shown.*

6/ *Effective at the station; a larger amount would be required at upstream sites.*

7/ *Assuming storage on areas shown would provide effective control of a 100-year flood.*

8/ *Storage required to effect optimum regulation at Jefferson.*

storage requirements at Goshen and Jasper, which are upstream from Eugene, are 194,000 and 568,000 acre-feet, respectively. However, these storages would regulate to 12,000 and 20,000 cubic-feet-per-second, respectively, at those stations, which would provide a regulation at Eugene of about 32,000 cfs. Thus, the upstream storage requirement is greater in this case than the downstream requirement because of the difference in channel capacities. For any other flow or for control at any other station, the storage requirement would be different. Effective control for any particular station (or reach) is influenced by the channel capacity and the susceptibility of the area to flood damage. Total storage requirements for the Portland harbor reach is predicated on a channel capacity of 200,000 cfs; however, the stage of Willamette River is markedly affected by the concurrent stage of Columbia River.

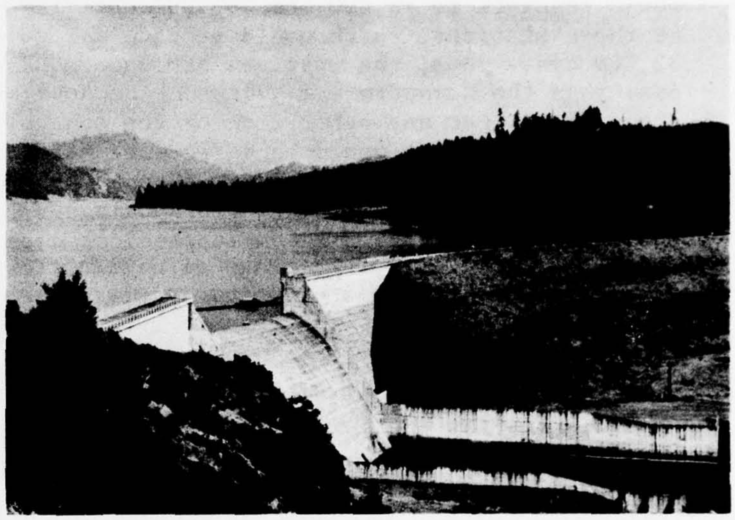
It should be noted that the amount of storage which would be required at an upstream site or sites generally will be more than the amount shown in Table IV-2 as a required new commitment. This is because the effect at each reservoir is partly dependent upon the operation of others in the system, desired regulation may be greater than the indicated regulation goal, and because the amount of storage which is economically justifiable may differ from the amount needed to control a 100-year flood. In addition, the amount of upstream storage that is effective at any control point is somewhat less than the amount that must be provided upstream. For example, the total flood control storage space at Fern Ridge Reservoir is 110,000 acre-feet, but only 104,500 acre-feet are effective at Monroe (control point for Long Tom River) because of downstream inflow and inability to exactly predict reservoir inflow and to regulate outflow accordingly. In that case, 110,000 acre-feet is the actual flood control storage and 104,500 acre-feet the effective flood control storage as far as control at Monroe is concerned.

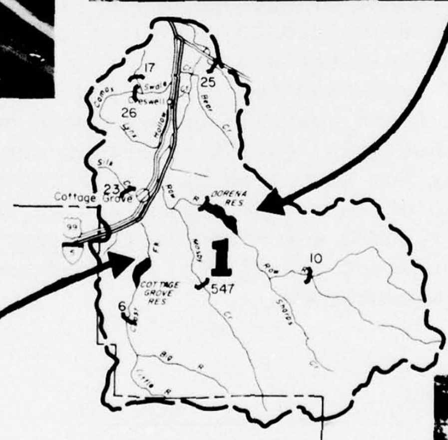
Subbasin 1 - Coast Fork

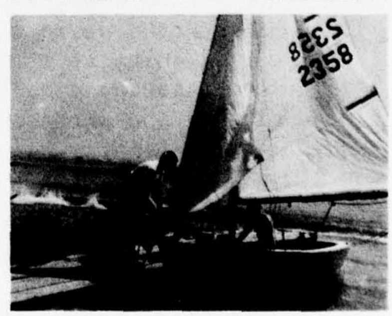
Subbasin 1, drainage area 665 square miles, is located on the north slope of the Calapooya Mountains. It constitutes the southwestern extremity of Willamette River Basin. Two existing reservoirs, Cottage Grove and Dorena on Coast Fork Willamette and Row Rivers, respectively, control runoff from a total of 369 square miles of the subbasin. There are no other authorized or assured reservoirs in the subbasin.

Effective control of a 100-year flood at Goshen, near the mouth of the Coast Fork, would require the provision of 194,000 acre-feet of storage capacity at that station. In consideration of 95,500 acre-feet of effective storage available at Cottage Grove and Dorena, and system flood routing for the subbasin, the remaining storage need would be approximately 98,500 acre-feet.

SUBBASIN 1 – COAST FORK







Modification of Existing Reservoirs

At Dorena Dam and Reservoir, a small amount of additional storage could be obtained by placing gates on the spillway crest. This would permit raising the pool to a higher elevation before involuntary spilling would occur. Operational studies show that an increment of flood control effectiveness could be obtained in this manner. A 10-foot-high gate would permit regulated use of about 20,000 acre-feet of space above the spillway crest. Such an addition could be made, and used, without endangering the stability of the existing structure. However, an increase of more than 5 feet, or 10,000 acre-feet, would inundate, to varying degrees, an existing relocated road and railroad and some existing recreation facilities; at present, all of those items are in the area which would be inundated at present maximum pool level. If single-purpose flood control regulation, by addition of gates, were to be considered in plan formulation, the problem of any periodic inundation of all those items would require evaluation and resolution.

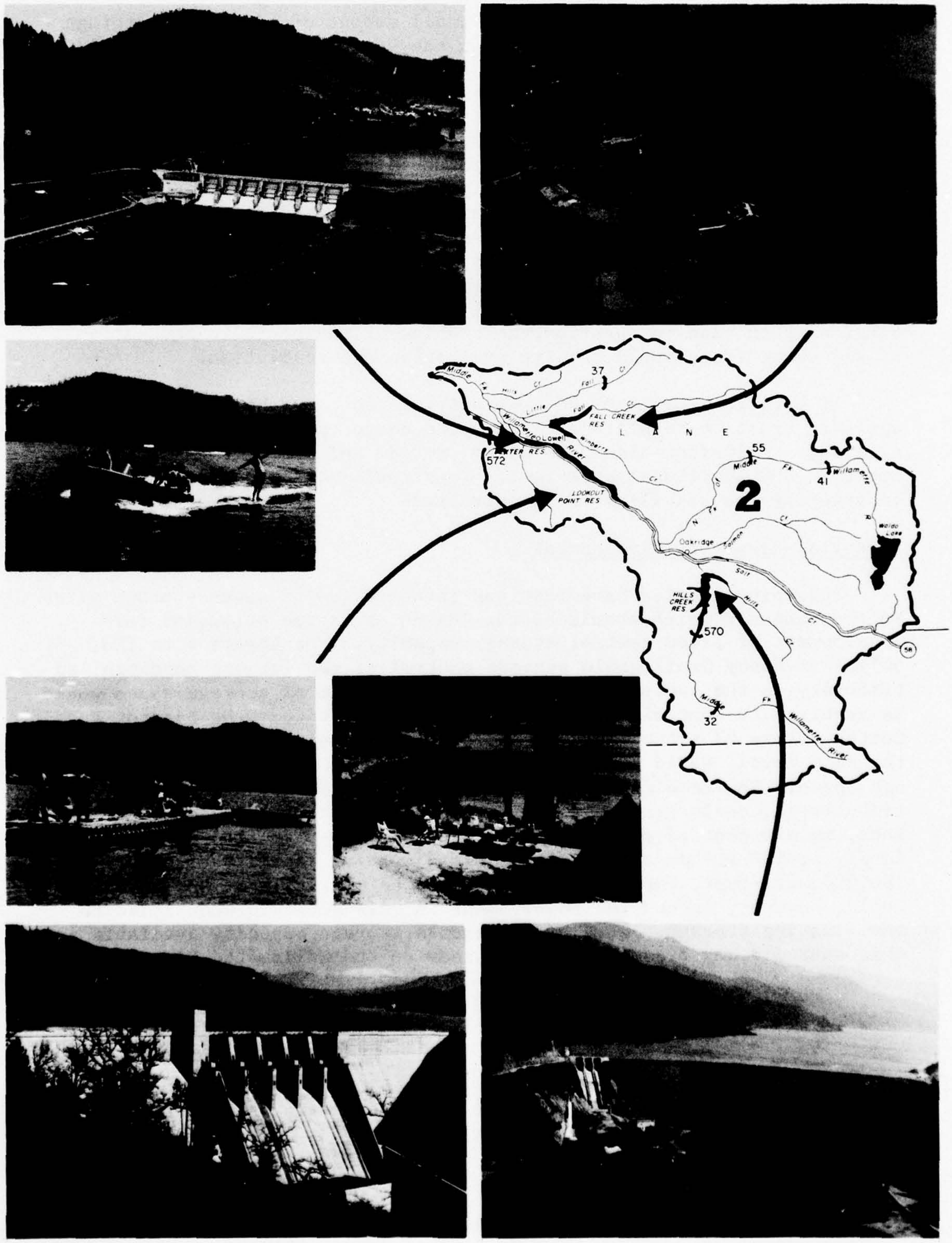
At Cottage Grove Dam and Reservoir, gates could be placed on the spillway crest to regulate storage space above the crest of the ungated spillway. A 10-foot-high gate would provide and permit regulation of about 10,000 additional acre-feet. This could be achieved without endangering the stability of the structure.

Potential Reservoir Development

Screening studies have resulted in selection of seven storage sites in the subbasin which should be considered as having potential for development of flood control storage capacity. The Abrams site (No. 547)[1/] on Mosby Creek would provide control of the largest uncontrolled tributary in the subbasin; about 45,000 acre-feet of storage space would be required to control a 100-year flood at that site. The Disston and Cottage Grove #3 sites (Nos. 10 and 6, respectively), if developed to the same level, would provide a total of about 100,000 acre-feet of storage space. The remaining four sites (Nos. 17, 23, 25, and 26), on small tributaries, could provide about 11,000 acre-feet of storage space. Thus, development of all seven sites, to the 100-year flood control level, would provide an additional flood control capacity of about 166,000 acre-feet. Not all of this would be effective at Goshen; it would, however, exceed the requirement in this subbasin when added to the existing storage. Some of the excess storage capacity available in this subbasin may be required downstream on the Willamette River.

1/ *See Map IV-1 for location and Table A-1, Addendum A, for reservoir-site data.*

SUBBASIN 2 — MIDDLE FORK



Subbasin 2 - Middle Fork

Subbasin 2, located in the southeast corner of the basin on the west slope of the Cascade Range, drains 1,354 square miles. Lookout Point and Hills Creek Reservoirs are located on the Middle Fork Willamette River, the principal stream in this subbasin; Fall Creek Reservoir is located on Fall Creek, an important tributary. These reservoirs control runoff from 1,175 square miles of drainage area. Two large tributaries in Subbasin 2, Little Fall Creek and Lost Creek, are uncontrolled.

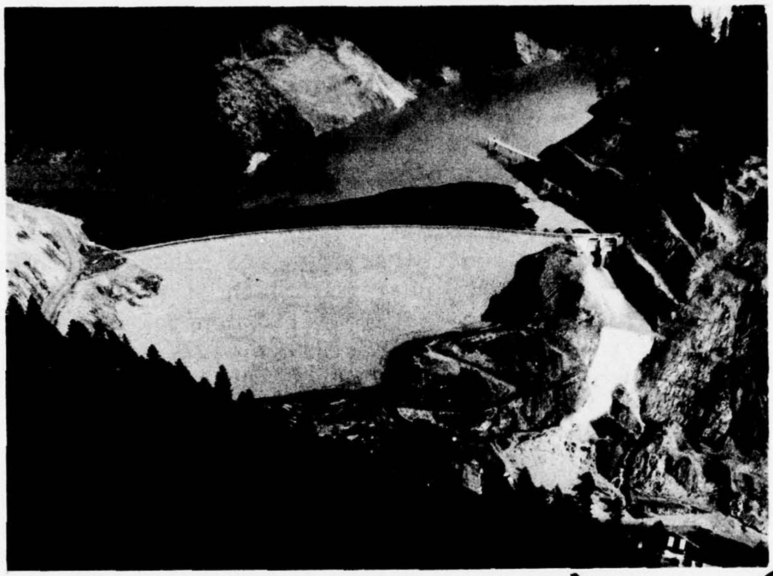
About 568,000 acre-feet of flood control storage are needed to effectively control a 100-year flood at Jasper, near the mouth of the Middle Fork. At present, 590,000 acre-feet of effective flood control storage space are available at Jasper from Lookout Point, Hills Creek, and Fall Creek Reservoirs. Thus, the need for effective flood control storage upstream from Jasper has been met, but additional storage in this subbasin could be used for flood control or other purposes downstream.

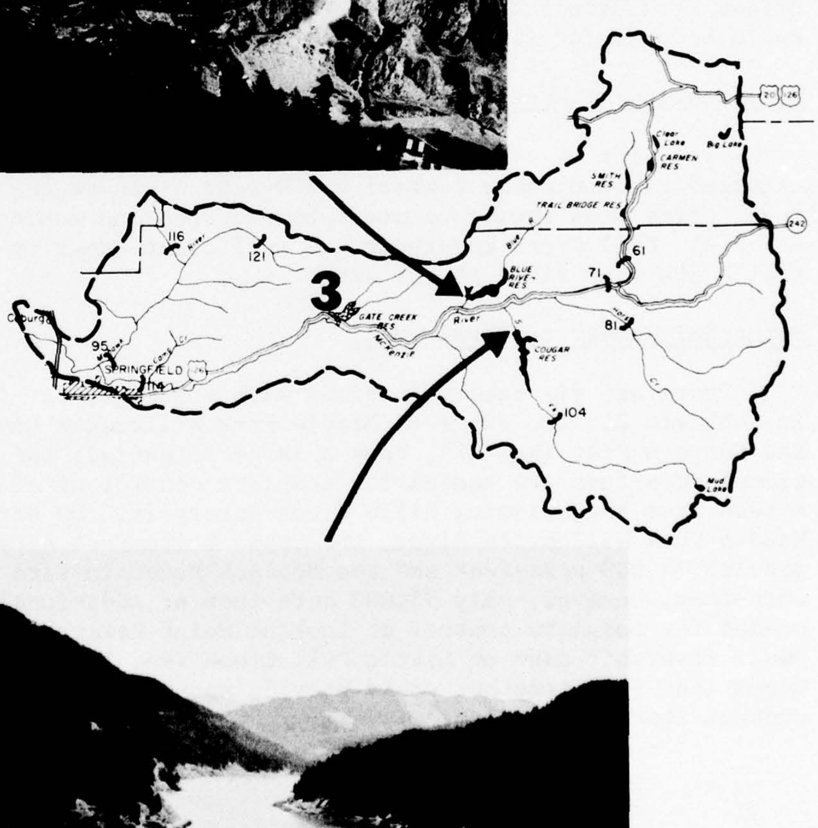
Modification of Existing Reservoirs

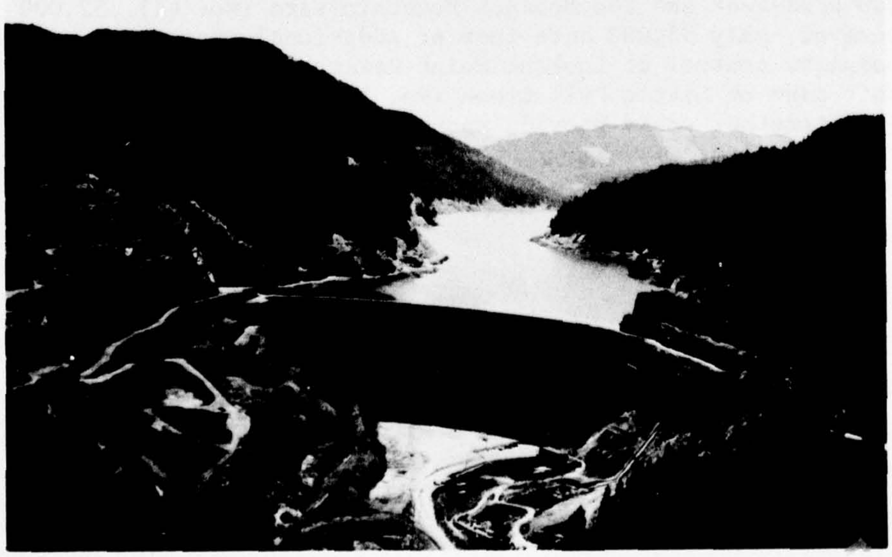
Two existing reservoirs, Lookout Point and Hills Creek, could be enlarged to completely control a 100-year flood at the site. However, major structural revisions would be required and would entail considerable expense. Fall Creek Reservoir has sufficient capacity to completely control a 100-year flood at the site.

Potential Reservoir Development

There are six reservoir sites with potential for flood control storage in Subbasin 2. Two sites on Middle Fork Willamette River, Mile 56 (No. 570) and Campers Flat (No. 32), have a large potential, but only 24,000 additional acre-feet are needed for complete control of a 100-year flood upstream from the existing Hills Creek Reservoir. On North Fork of Middle Fork Willamette River, the Upper North Fork site (No. 55) could provide 74,000 acre-feet and the Moolack Mountain site (No. 41), 52,000 acre-feet; however, only 38,000 acre-feet of additional storage are needed for complete control at Lookout Point Reservoir downstream. A small reservoir site on Little Fall Creek (No. 37) and on Rattlesnake Creek (No. 572) together could provide about 8,200 acre-feet of flood control storage capacity.




3
20
126
242
Clear Lake
Big Lake
CARMEN RES
SMITH RES
TRAIL BRIDGE RES
116
121
61
71
BLUE RIVER RES
GATE CREEK RES
River
McKenzie
81
COUGAR RES
95
SPRINGFIELD
114
104
Mud Lake



Subbasin 3 - McKenzie

Subbasin 3 is located on the west slope of the Cascade Range immediately north of Middle Fork Subbasin. McKenzie River, its principal stream, drains 1,342 square miles. The existing and authorized reservoirs, located on principal tributaries of the McKenzie, are Gate Creek, Blue River, and Cougar, which together control runoff from 346 square miles of drainage area. The largest uncontrolled tributaries are White Branch of Lost Creek, Horse Creek, Quartz Creek, and Mohawk River.

To effectively control a 100-year flood at Coburg, near the McKenzie River mouth, 600,000 acre-feet of storage are needed. The combined flood control storage capacity of the three existing reservoirs effective at Coburg is 245,000 acre-feet. Thus, the unmet need for flood control storage is 355,000 acre-feet.

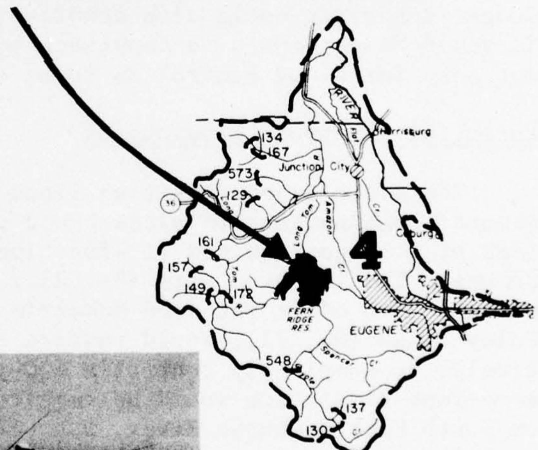
Modification of Existing Reservoirs

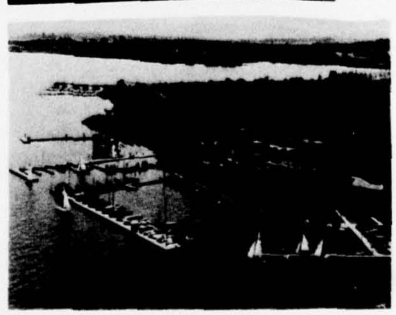
Gate Creek and Blue River Reservoirs have sufficient capacity to contain a 100-year flood at the site. With an additional 3,000 acre-feet, Cougar Reservoir could also completely control a 100-year flood. Thus, it would be necessary to construct one or more new reservoirs if the unmet need for flood control is to be satisfied by storage.

Potential Reservoir Development

There are eight potential flood control storage sites in Subbasin 3. Several combinations of sites could provide the additional 355,000 acre-feet of storage required to effectively control the McKenzie River at Coburg. The Thurston site (No. 114) on McKenzie River could provide this amount. Two other sites on McKenzie River, Twisty Creek (No. 61) and Foley Ridge (No. 71), would require 88,000 and 130,000 acre-feet, respectively, to completely control a 100-year flood at the site. About 94,000 acre-feet of storage would be required at the Rebel Creek site (No. 104) on South Fork McKenzie River, but only 3,000 additional acre-feet are needed at Cougar Reservoir to completely control a 100-year flood at the site. Mohawk site (No. 95) on Mohawk River, and Horse Creek site (No. 81) on Horse Creek are other large reservoir sites with flood control potential. A site on Upper Mohawk River (No. 121) and one on Shotgun Creek (No. 116) could provide a total of 10,300 acre-feet.

SUBBASIN 4 — LONG TOM





Subbasin 4 - Long Tom

Subbasin 4 is located on the east slope of the Coast Range, immediately north of Subbasin 1. Long Tom River, its principal stream, drains 410 square miles of the subbasin's total area of 526 square miles. Fern Ridge, the only existing reservoir, provides 110,000 acre-feet of flood control storage space and controls runoff from 275 square miles of drainage area. The principal uncontrolled tributaries are Bear and Ferguson Creeks.

About 143,000 acre-feet are needed to completely control a 100-year flood at Monroe. Fern Ridge Reservoir provides 104,500 acre-feet of storage effective at Monroe. Thus, the unmet need for flood control storage is 38,500 acre-feet. Even if this amount were provided, the Long Tom River would not be effectively controlled all the way to its mouth.

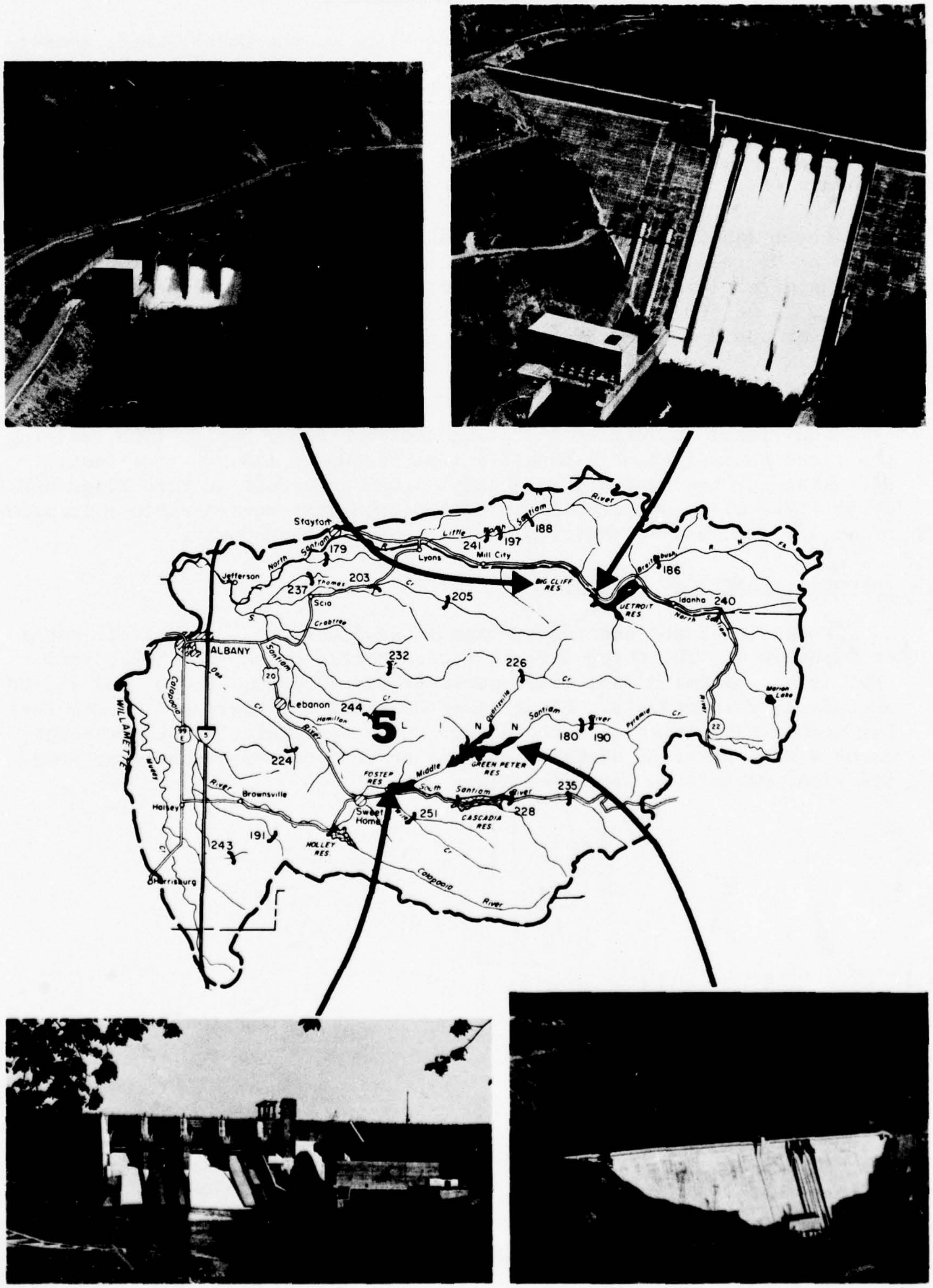
Modification of Existing Reservoir

Additional embankment was placed at Fern Ridge Dam in 1965, raising the flood control storage capacity from 95,000 to 110,000 acre-feet. Provision for the needed storage of 143,000 acre-feet at Fern Ridge would necessitate major structural revision of the dam, considerable relocation of facilities, and acquisition of additional right-of-way.

Potential Reservoir Development

Potential flood control storage is available at 12 reservoir sites in Subbasin 4. The three largest sites--Battle Creek (No. 548), Noti (No. 172), and Smith (No. 161)--could provide 35,000, 30,000, and 17,500 acre-feet, respectively. Eight sites on small tributaries (see Map IV-1 for numbers and locations) could provide an aggregate 15,800 acre-feet; about 4,000 acre-feet of this total is on tributaries which enter Long Tom River downstream from Fern Ridge Dam.

SUBBASIN 5 — SANTIAM



Subbasin 5 - Santiam

Subbasin 5 encompasses about 2,440 square miles. Two major tributaries of the Willamette--Santiam and Calapooia Rivers--drain this subbasin. This subbasin is located on the west slope of the Cascades immediately north of the Subbasin 3, occupying the east-central sector of Willamette Basin.

Santiam River Drainage

The Santiam has two principal tributaries, North Santiam and South Santiam Rivers, each with a large tributary--Little North Santiam and Middle Santiam Rivers, respectively. Little North Santiam River, Crabtree Creek, and Thomas Creek are the principal uncontrolled tributaries. Santiam River drains 1,790 square miles upstream from the Jefferson gaging station, which is a few miles from the mouth of that stream.

Three existing reservoirs provide considerable control of floods in the Santiam drainage, and an authorized reservoir will add more control capability in the near future. Detroit Reservoir, on North Santiam River, provides 300,000 acre-feet of flood control storage space. Green Peter Reservoir on the Middle Santiam provides 270,000 acre-feet, and Foster and Cascadia (authorized) on the South Santiam 30,000 and 145,000 acre-feet, respectively.

Total storage needed is 800,000 acre-feet for effective of Santiam River at Jefferson. The reservoirs noted provide 595,000 acre-feet of effective storage. Thus, the unmet need for effective flood control storage at Jefferson is 205,000 acre-feet.

Modification of Existing Reservoirs.--Detroit Reservoir would require a 60,000 acre-foot enlargement to completely control a 100-year flood at the site. However, this would require major structural revision. Green Peter and Cascadia Reservoirs have the capability to completely control a 100-year flood at the site.

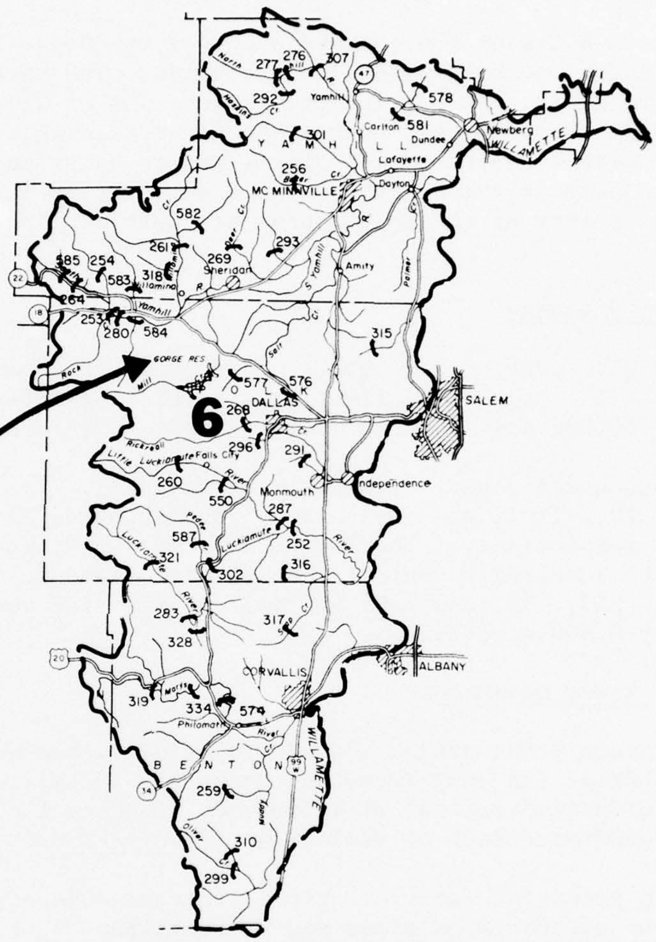
Potential Reservoir Development.--Six potential sites are available in the North Santiam drainage, and 11 in the South Santiam (see Map IV-1 for numbers and locations). However, five large sites in the latter are upstream from existing and authorized reservoirs which completely control a 100-year flood at the site, and thus would provide little additional control capability. Only the sites on streams upstream from Detroit Reservoir, on the Little North Santiam, and on Wiley, Thomas, and Crabtree Creeks offer large potential for flood control storage. Three or more of these sites could provide the additional 205,000 acre-feet of effective storage needed to obtain effective control of the Santiam River at Jefferson, but areal control would still be lacking. Three sites on small tributaries could provide an aggregate 10,650 acre-feet of storage for flood control.

Calapooia River Drainage

Calapooia River drains 372 square miles at the Albany gaging station, near the mouth. The total storage required to effectively control Calapooia River at Albany is 130,000 acre-feet. The authorized Holley Reservoir (total flood control storage 90,000 acre-feet)on Calapooia River, will control a 100-year flood at the site. Flood control storage alone would not be effective in reducing downstream flood stages unless channel improvement work is also accomplished. The stream channel capacity is restricted, so that flood control storage cannot be operated to control runoff from recurring floods. Storage at Holley will not provide effective control all the way to the Calapooia River mouth because it does not control runoff from enough of the drainage area. No suitable storage site exists further downstream.

Three reservoir sites are available on small, uncontrolled tributaries in Calapooia drainage, with an aggregate storage capacity of 4,550 acre-feet. These are on Courtney, Oak, and Little Muddy Creeks (reservoir sites Nos. 191, 224, and 243, respectively).

SUBBASIN 6 – COAST RANGE



DAM SITE
APRIL 28, 1964

DECEMBER 23, 1964

Subbasin 6 - Coast Range

Subbasin 6 drains the eastern slope of the Coast Range, occupying the west-central portion of Willamette Basin. The basin encompasses 1,794 square miles. Four principal tributaries of Willamette River drain this subbasin--Marys River, Luckiamute River, Rickreall Creek, and Yamhill River, in south-to-north order. There are no existing or authorized flood control projects in the basin. Gorge Reservoir, on Mill Creek, is considered to be part of the base system as a project assured under other authority.

Marys River Drainage

Marys River drains 159 square miles at the Philomath gaging station, river mile 9.4. To obtain effective control of a 100-year flood at Philomath, 50,000 acre-feet of flood control storage are needed.

Six potential reservoir sites are available. The Wren (No. 334) or Noon (No. 574) sites, on Marys River, could provide 72,500 and 77,500 acre-feet, respectively. The Tumtum site (No. 319) would require 28,500 acre-feet to completely control the 100-year flood at the site. Three sites (Nos. 259, 299, and 310) on small tributaries together could provide nearly 8,000 acre-feet.

Luckiamute River Drainage

Luckiamute River drains 240 square miles at the Suver gaging station near the mouth. Its only important tributary is Little Luckiamute River. To obtain effective control of a 100-year flood on Luckiamute River at Suver, 105,000 acre-feet of storage would be required.

Eleven potential reservoir sites are available--five large and six small. Four of the large sites are on Luckiamute River and one on the Little Luckiamute. Only the Airlie site (No. 252) on Luckiamute River could provide sufficient storage to effectively control a 100-year flood on Luckiamute River at the Suver gage. Of the other sites, two or more would be required. About 23,000 acre-feet of flood control storage could be provided by the six small reservoir sites.

Rickreall Creek Drainage

Rickreall Creek drains 27 square miles upstream from the Dallas gaging station. The Dallas site (No. 268), the only potential reservoir on this stream, would control runoff from more than that area and provide effective flood control at the town of Dallas. The requirement for complete control at the site is 25,000 acre-feet. Rickreall Creek cannot be completely controlled all the way to its mouth by this reservoir.

Yamhill River Drainage

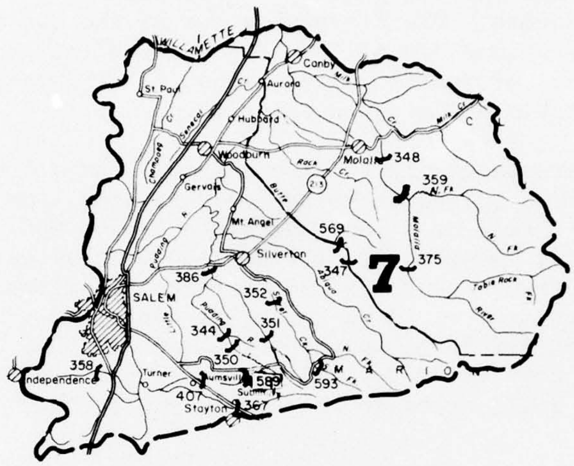
Yamhill River has two principal tributaries, North Yamhill and South Yamhill Rivers. The drainage areas of the two streams at their lowest gaging stations are 67 and 502 square miles, respectively. Effective control of Yamhill River cannot be achieved by storage because not enough suitable sites are available.

At the Whiteson gaging station on South Yamhill River, which measures runoff from a 502-square-mile drainage area, the storage requirement for effective control of a 100-year flood is 145,000 acre-feet. Gorge Reservoir on Mill Creek would provide 21,000 acre-feet effective at Whiteson; therefore, about 124,000 acre-feet of flood control storage at appropriate locations would be needed to control South Yamhill River. At Pike damsite (No. 307), on the North Yamhill, 57,000 acre-feet would be required to completely control a 100-year flood at the site, but some flooding would still occur in the downstream part of the North Yamhill flood plain.

In the Yamhill River drainage, there are 21 reservoir sites with potential for flood control storage. Of the 10 large sites (10,000 acre-feet or more), seven are in the South Yamhill drainage and three in the North Yamhill. In the South Yamhill, it would take at least three reservoirs to obtain the 124,000 acre-feet of the storage needed to effectively control the South Yamhill River at Whiteson. The 57,000 acre-feet of storage needed to completely control a 100-year flood at the Pike site in the North Yamhill would lower the stages considerably along Yamhill River when operated in conjunction with reservoirs in the South Yamhill drainage; however, effective control cannot be achieved by storage alone. There are eight small reservoirs in the South Yamhill drainage and three in the North Yamhill; some of these sites would rule out, or be ruled out by, large reservoir development.

Minor Tributaries

Five small reservoir sites (Nos. 291, 296, 315, 578, and 581) have a potential for flood control storage on small tributaries emptying directly into Willamette River between Independence and Newberg. Aggregate capacity of these sites is about 3,000 acre-feet.



Subbasin 7 - Pudding

Subbasin 7 drains some of the lower mountains on the west slope of the Cascades; it does not extend to the eastern boundary of Willamette Basin. The subbasin contains 1,186 square miles. Its principal streams are Pudding and Molalla Rivers, which drain about 530 and 350 square miles, respectively. Mill Creek, emptying into Willamette River at Salem, drains about 110 square miles in the southwest corner of this subbasin. There are no existing flood control reservoirs. The storage requirement on Pudding River for effective control of a 100-year flood at Aurora is 150,000 acre-feet. For this level of protection on Molalla River at Canby, 75,000 acre-feet would be required.

Pudding River Drainage

Development of all reservoir sites with flood control storage potential would not provide the 150,000 acre-feet of storage needed to effectively control Pudding River at Aurora. A site on Pudding River (No. 386), one on Silver Creek (No. 352), and two on Butte Creek (Nos. 347 and 569) could provide 22,000,34,000, 26,000, and 30,000 acre-feet of storage, respectively. Four small sites could provide an aggregate capacity of about 9,000 acre-feet.

Molalla River Drainage

Any of the three large sites in the Molalla drainage--Dickey Bridge (No. 348), North Fork (No. 359), or Pelkey (No. 375)--could provide more than enough storage to effectively control the river at Canby. No small reservoir sites were studied in this drainage.

MOLALLA RIVER
DECEMBER 24, 1964 FLOOD

Mile 19, From right bank

Liberal, from left bank looking downstream

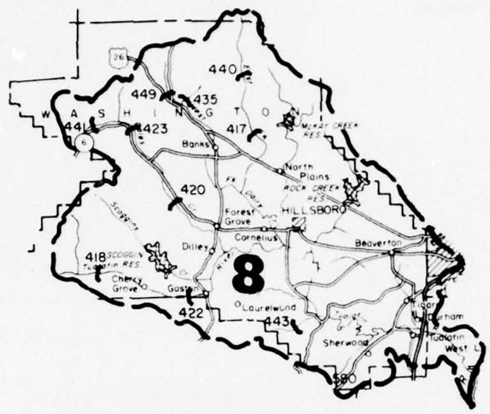
Shady Dell Bridge looking downstream

Goods Bridge looking upstream

Mile 2 -1/2 from left bank

Mill Creek Drainage

Four small reservoir sites in the Mill Creek drainage (Nos. 358, 367, 407, and 589) are available for flood control storage. Their aggregate storage capacity is about 11,200 acre-feet. Flooding on the lower reaches of Mill Creek could not be effectively controlled by storage because these sites are too far upstream.



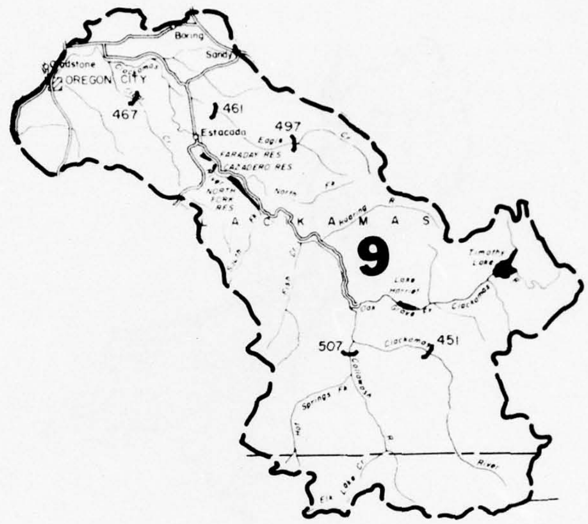
<u>Subbasin 8 - Tualatin</u>

Subbasin 8 encompasses 711 square miles in the northwestern part of Willamette Basin. Tualatin River is the principal stream, draining 706 square miles. Storage requirements for effective control of Tualatin River at West Linn (near its mouth) are 294,000 acre-feet.

There are no existing or authorized flood control storage projects in this subbasin. The authorized Scoggins Reservoir would provide incidental flood control benefits, but no storage is specifically allocated for that purpose. McKay Creek-Rock Creek Project--considered part of the base system--would provide 12,700 acre-feet of flood control storage. Thus, the unmet need for flood control storage in this subbasin is 281,300 acre-feet.

Storage alone, however, will not be effective in reducing downstream flood damages until stream channel improvement has been accomplished, because the downstream channel capacity is restricted and flood control storage could not be effectively evacuated. Channel improvement potential is discussed in subsequent text.

Even if all potential reservoirs were developed to a capacity sufficient to completely control a 100-year flood at the site, floods still would not be effectively controlled all the way to the mouth of the Tualatin River. Four sites--Gales Creek (No. 420) and Glenwood (No. 423) on Gales Creek, Gaston (No. 422) on Tualatin River, and East Fork Dairy Creek (No. 417) on the same-named stream-- offer between 26,500 and 43,000 acre-feet of storage. Six small sites (Nos. 418, 435, 440, 441, 443, and 449) could provide an aggregate 24,000 acre-feet of flood control storage.



Subbasin 9 - Clackamas

Subbasin 9, containing about 1,014 square miles, is located in the northeasterly portion of Willamette Basin. Clackamas River is the principal stream, draining about 936 square miles at the Clackamas gaging station, near the mouth. The storage requirement for effective control of a 100-year flood at the Clackamas gage is about 305,000 acre-feet. There are no existing or authorized flood control projects in the basin, but Portland General Electric Company power projects at River Mill, Faraday, Cazadero, North Fork, and Harriet and Timothy Lakes provide some minor and incidental flood control benefits.

Modification of Existing Reservoirs

The Timothy Lake Reservoir contains about 61,650 acre-feet of usable storage space, of which 45,000 acre-feet would be required for complete control of the 100-year flood at the site. An enlarged outlet would be needed for effective flood control operation. Before this alternative could be used, however, provision for adequate compensation would have to be negotiated with the power company.

Potential Reservoir Development

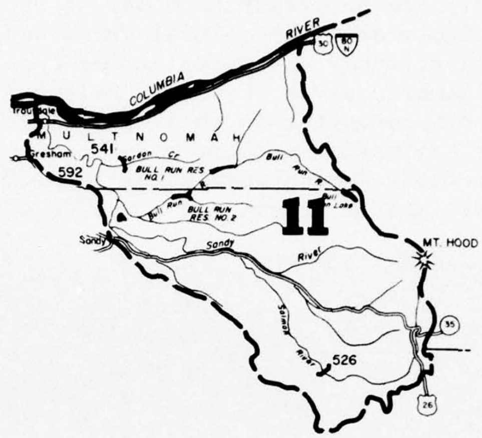
Five reservoir sites--four large--are available to control floods in Clackamas Subbasin. The sites are located on Clackamas River (No. 451), Collawash River (No. 507), Clear Creek (No. 467), and two (Nos. 461 and 497) on Eagle Creek. The three largest sites would provide the required storage, but areal control would still be lacking even if all potential sites were developed.

SUBBASIN 10 – COLUMBIA

Subbasin 10 - Columbia

Subbasin 10, containing about 431 square miles, is located in the northern end of the basin and is an area designation, rather than a drainage basin. Most of the Portland metropolitan area lies in this subbasin.

All the tributary streams are short and drain small areas. The principal streams are Johnson, Scappoose, and Milton Creeks. There are no existing or authorized flood control storage projects in the area, and no flood control storage sites have been found which would provide effective control. However, some reduction of floodflows could be provided by storage. Most of the major flood threat is along Willamette River; flooding along Johnson Creek in and east of Portland is also a perennial problem.



Subbasin 11 - Sandy

Subbasin 11, containing about 582 square miles, is located in the northeastern corner of Willamette Basin. Sandy River is the principal stream, draining 502 square miles. There are no existing or authorized flood control projects in this subbasin, but the Portland municipal water supply storage reservoirs offer some incidental benefits. Since Sandy River does not empty into the Willamette, storage would provide benefit only within the subbasin.

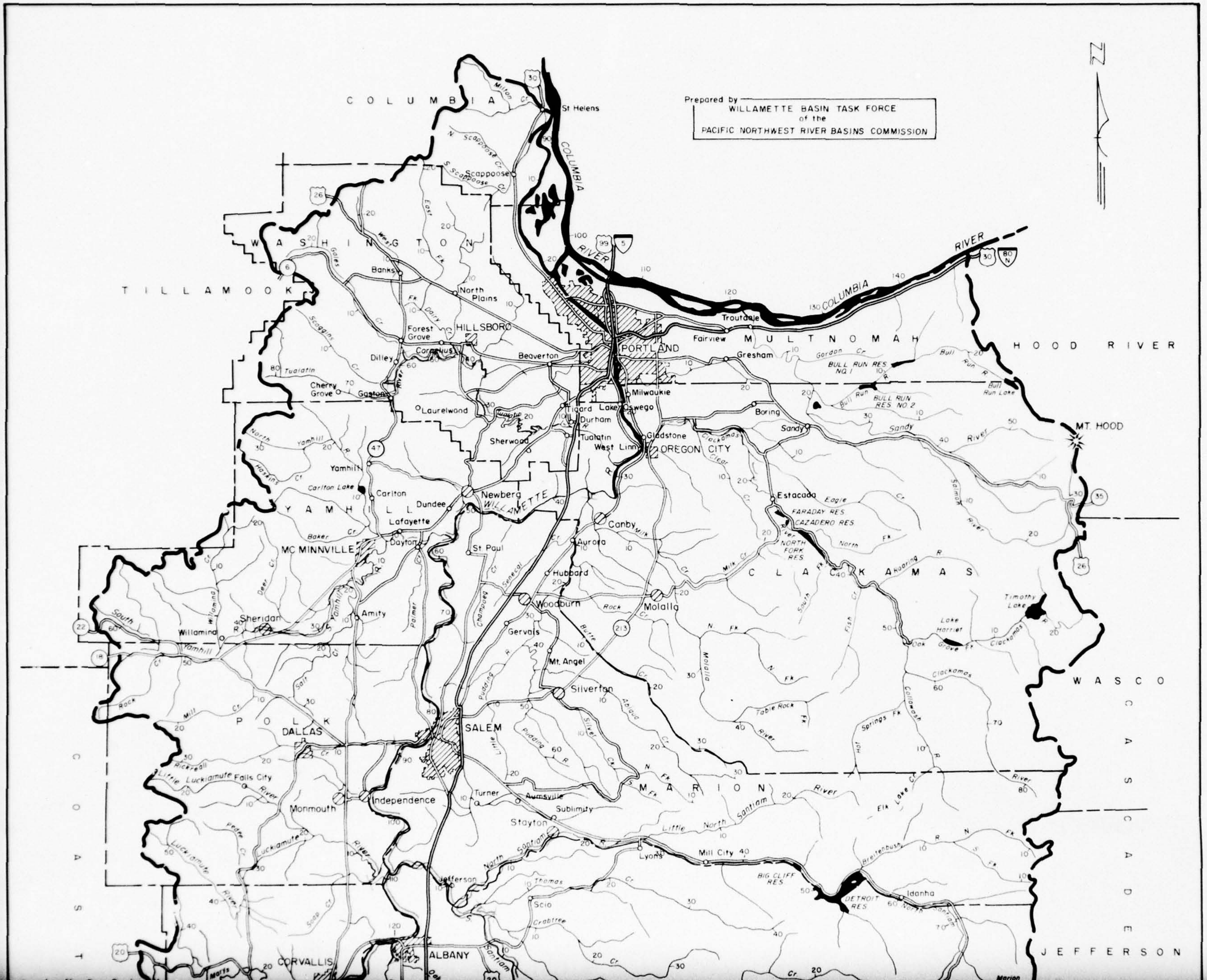
To effectively control the Sandy River at Troutdale, 200,000 acre-feet of storage would be required. The two potential flood control storage sites, Linney Creek (No. 526) and Gordon Creek (No. 541), could provide only 29,300 and 5,200 acre-feet, respectively. There are no effective flood control storage sites in the downstream reaches of Sandy River. Thus, storage is not considered a solution to the flood problem in this subbasin.

LEVEES

Levees potentially are an effective means of reducing flood damages where protection of highly damageable local areas and facilities is desired. In the absence of other measures, almost continuous levees would be required along Willamette River and major tributaries, essentially from their mouths to the perimeter foothills, to completely control a 100-year flood. For cost estimating purposes, and for economic evaluation, detailed backwater profiles were prepared for the 100-year flood by electronic computer for Willamette River, and compared with high water-marks

Photo IV-1 A disadvantage of levees is that they can be circumvented by high floodwaters. Clackamas River, December 1964. (USCE Photo)

from the December 1964 flood to verify accuracy. Generally, flood profiles along major tributaries were prepared from crest-stage readings from the 1964 flood. Levee alignment was dictated by topography, and an attempt to balance hydraulic requirements with property protection in the flood plain. See Map IV-2 for general location. Costs were based on earthfill levees with side slopes of three on one, and 12-foot top width except for revetted portions. Portions requiring revetment would be built with two on one side slopes. Costs were computed for containment of the 100-year flood regulated by existing, authorized and presently assured projects allowing for a 3-foot freeboard in rural areas and 4-foot in urban areas (see Table IV-1). Costs were also prepared for intermediate


Prepared by
WILLAMETTE BASIN TASK FORCE
of the
PACIFIC NORTHWEST RIVER BASINS COMMISSION
COLUMBIA
WASHINGTON
TILLAMOOK
YAMHILL
POLK
MARION
CLACKAMAS
MULTNOMAH
HOOD RIVER
WASCO
JEFFERSON
LINCOLN
COAST
CASCADE
COLUMBIA RIVER
WILLAMETTE
St Helens
Scappoose
Banks
North Plains
Forest Grove
HILLSBORO
Cornelius
Dilley
Gaston
Cherry Grove
Laurelwood
Beaverton
PORTLAND
Troutdale
Fairview
Gresham
Milwaukie
Tigard
Lake Oswego
Durham
Tualatin
West Linn
Gladstone
OREGON CITY
Sherwood
Newberg
Dundee
Lafayette
Carlton
Yamhill
Dayton
MC MINNVILLE
Sheridan
Willamina
Amity
St Paul
Aurora
Canby
Hubbard
Woodburn
Molalla
Gervais
Mt. Angel
Silverton
SALEM
DALLAS
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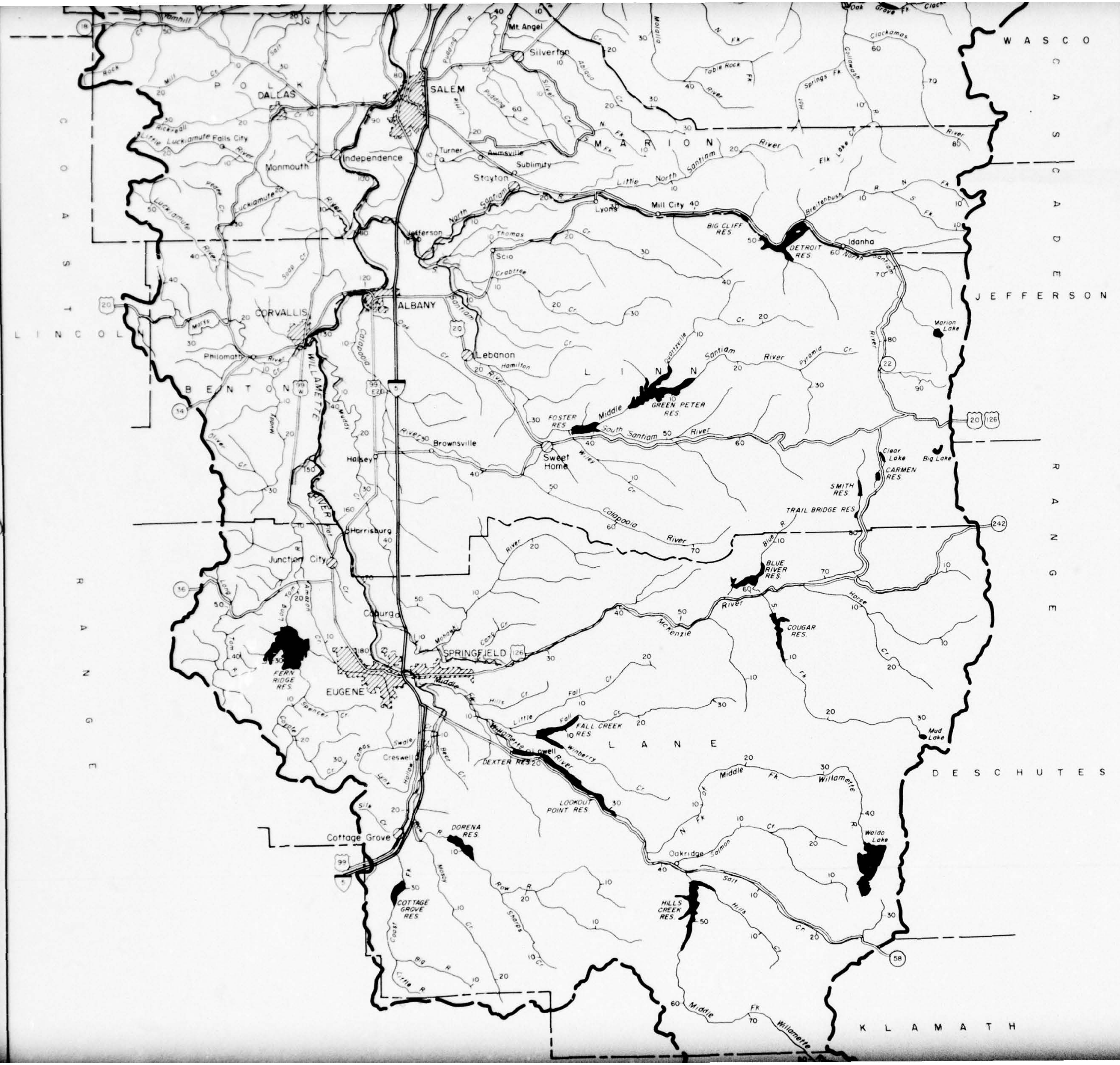
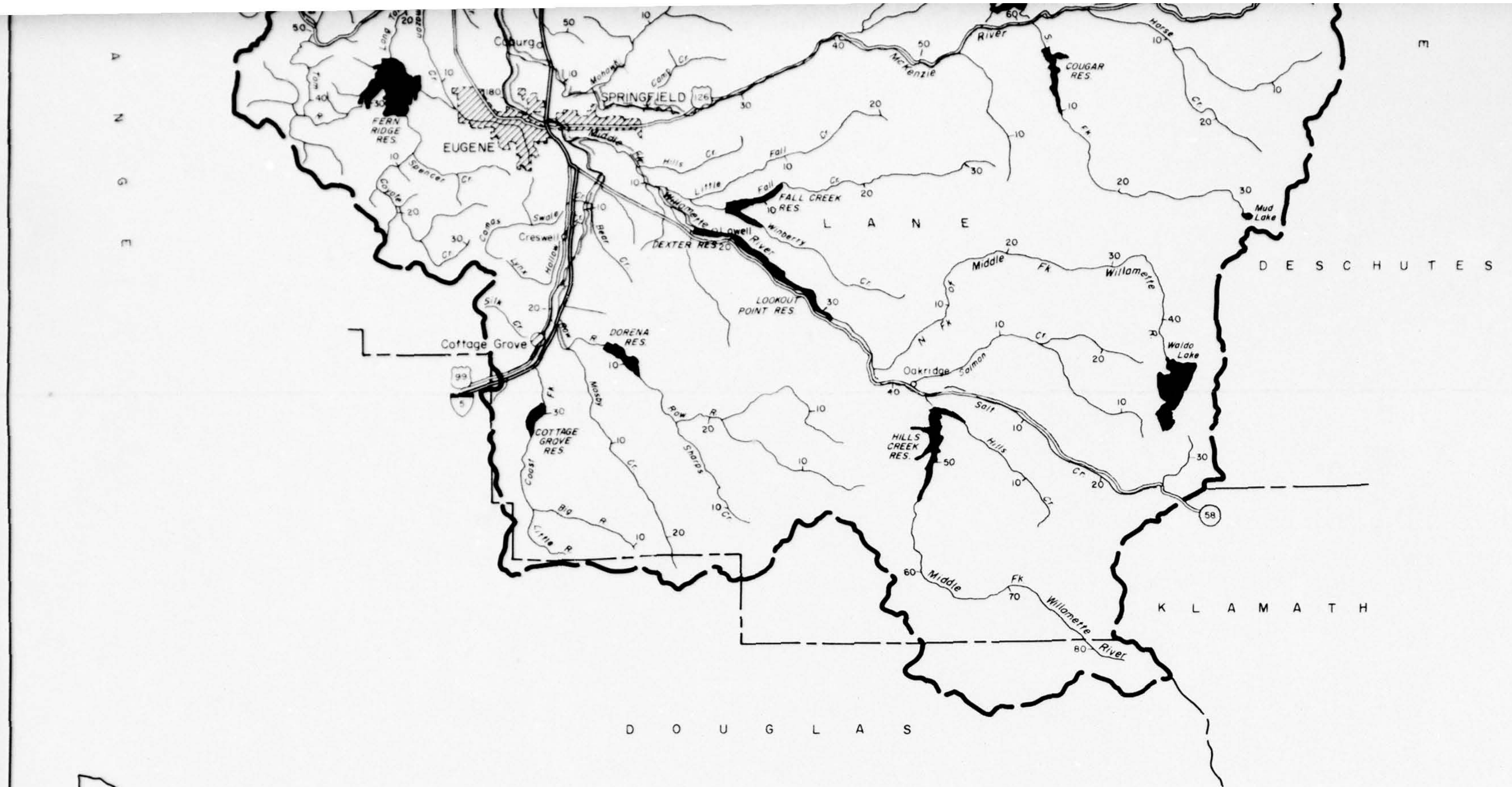
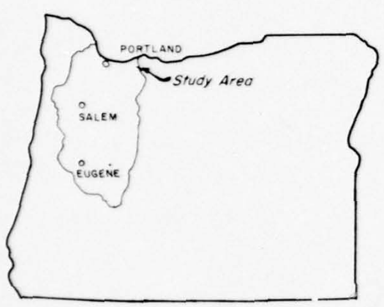
MT. HOOD
Timothy Lake
Lake Harriet
BULL RUN RES NO. 1
BULL RUN RES NO. 2
Bull Run Lake
FARADAY RES
CAZADERO RES
NORTH FORK RES
BIG CLIFF RES
DETROIT RES
Marion Lake
Carlton Lake


WASCO
CASCADE
JEFFERSON
RANGE
DESCHUTES
KLAMATH
COAST
RANGE
LINCOL
POLK
MARION
LINN
BENTON
LANE
SALEM
Silverton
Mt. Angel
DALLAS
Independence
Monmouth
Falls City
Turner
Aumsville
Sublimity
Stayton
Lyons
Mill City
Idanha
Jefferson
Scio
ALBANY
CORVALLIS
Philomath
Lebanon
Brownsville
Halsey
Harrisburg
Sweet Home
Junction City
Coburg
SPRINGFIELD
EUGENE
Creswell
Cottage Grove
Oakridge
WILLAMETTE
DETROIT RES
BIG CLIFF RES
GREEN PETER RES
FOSTER RES
SMITH RES
TRAIL BRIDGE RES
CARMEN RES
Clear Lake
Big Lake
Marion Lake
BLUE RIVER RES.
COUGAR RES.
FALL CREEK RES
DEXTER RES
LOOKOUT POINT RES
DORENA RES
COTTAGE GROVE RES
HILLS CREEK RES
FERN RIDGE RES.
Waldo Lake
Mud Lake
2





LEGEND

Generalized levee location

Levee requirements indeterminant beyond this point.

MAP IV - 2

WILLAMETTE BASIN STUDY

OREGON

POTENTIAL LEVEES

1968

6 0 6 12

SCALE IN MILES

Note:
Levee requirements needed in absence of other flood control measures for control of 100-year flood.

WBTF-O-1127ad-LL

flows comparable to, and compatible with, a flow of 135,000 cfs at Salem. These costs along with the bankfull (no damage) stage were used for plotting the cost curves. Costs shown include rights-of-way, necessary relocations, revetments, pumps, and drainage facilities appurtenant to the levee construction.

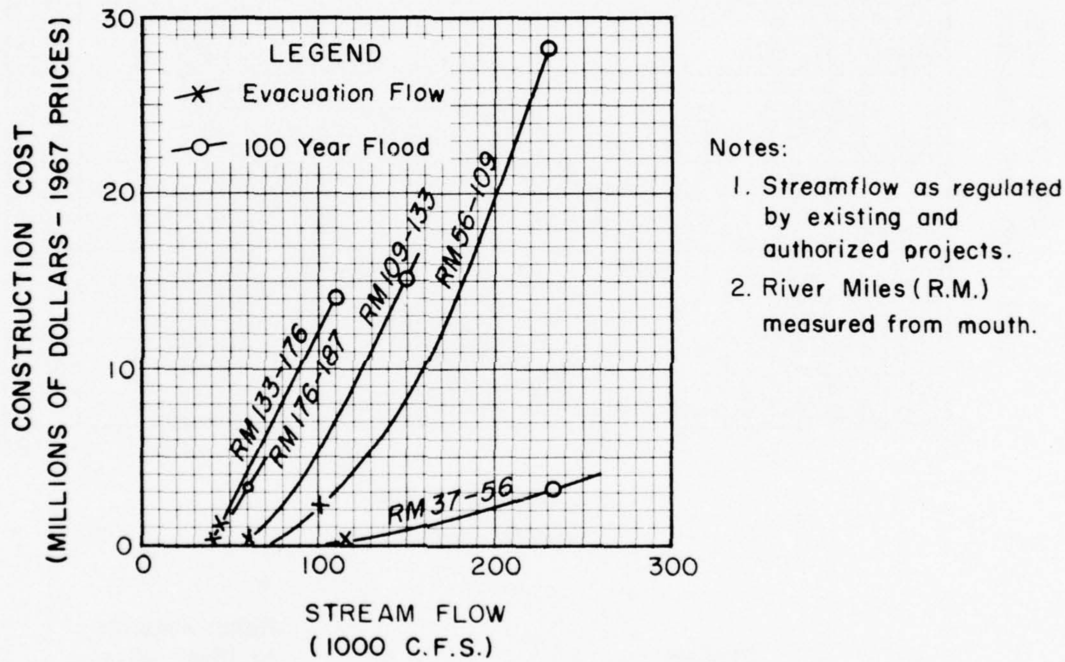
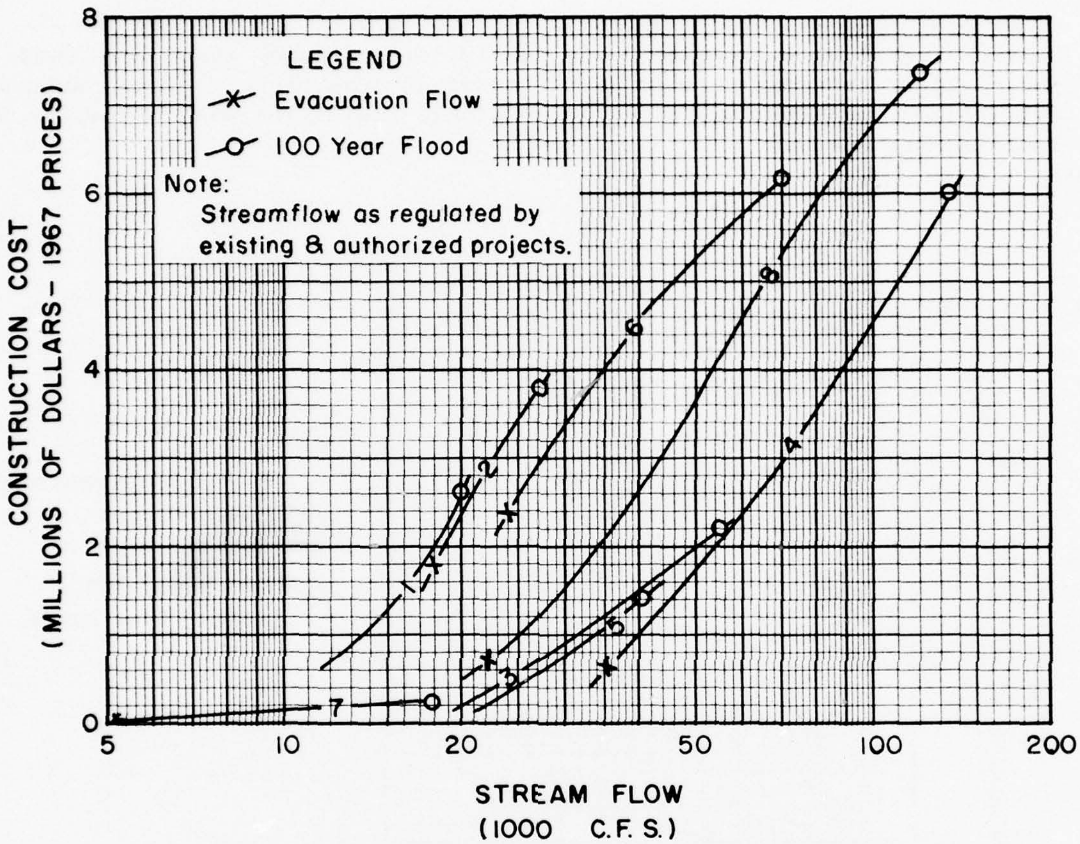
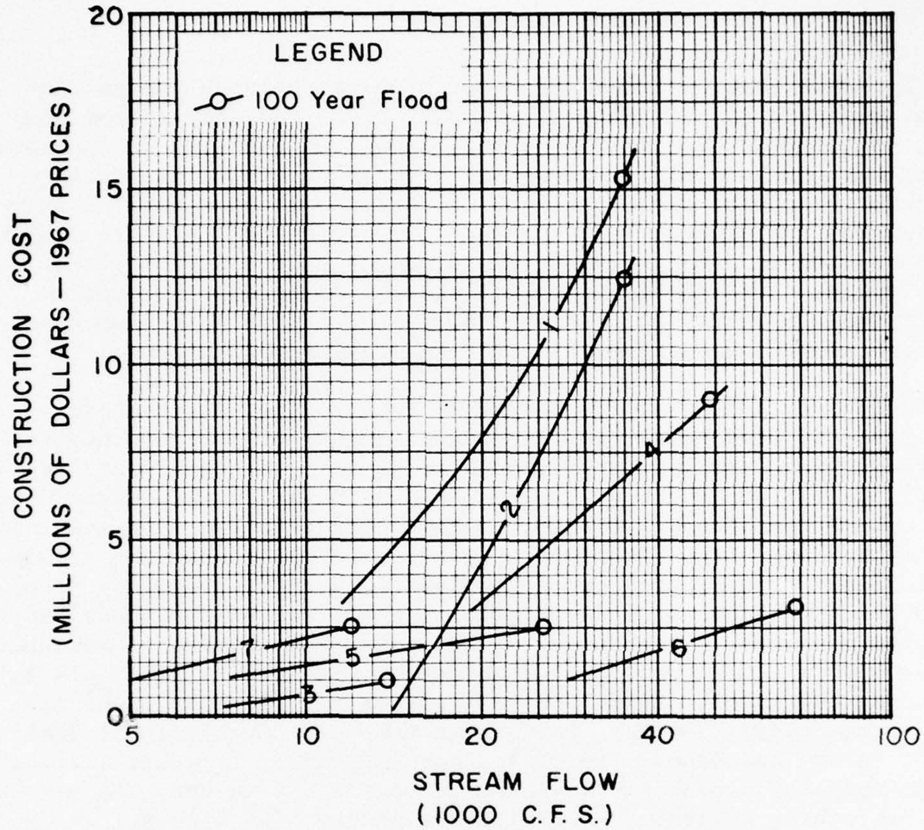


Figure IV-1a Potential levees, Willamette River



	Stream	Flow at	Reach - Mouth to River Mile
1.	Thomas Creek	Scio	18
2.	South Santiam River	Waterloo	37
3.	North Santiam River	Mehama	46
4.	Santiam River	Jefferson	12
5.	Mid. Fork Willamette R.	Jasper	45
6.	McKenzie River	Coburg	82
7.	Row River	Dorena dam	7
8.	Clackamas River	Estacada	30

Figure IV-1b Potential levees, east-side tributaries



Stream	Flow at	Reach—Mouth to River Mile
1. Luckiamute River and Little Luckiamute R.	Suver	28 7
2. Coast Fork Willamette R.	Goshen	29
3. Marys River	Bellfountain Road	13
4. South Yamhill River	Whiteson	45
5. North Yamhill River	Highway 99W	10
6. Yamhill River	Dayton	11
7. Rickreall Creek	Mouth	8

Figure IV-1c Potential levees, west-side tributaries

CHANNEL IMPROVEMENT

Much can be done to alleviate flood problems by such channel improvement measures as clearing and snagging brush and debris from the channel, realignment to eliminate sharp bends, and dredging of sandbars and deposits. In general, clearing and snagging would be appropriate where needs are minor; any major need probably could be satisfied only by realignment and enlargement. Caution must be exercised in realigning the channel, and in dredging, that the gradient of the stream is not made too steep, thus increasing the velocity and aggravating erosive action of the stream. Also, channel improvements must be designed so that recreational environments will be preserved for future use.

Dredging could be used to enlarge the channel for floodwaters. This measure, if used alone, would require removal of large quantities of material. For example, improvements to contain an eight-year frequency flood (135,000 cubic feet per second at Salem) within banks would require excavation of about 85,000,000 cubic yards in the 150-mile reach of Willamette River from Wilsonville upstream to the confluence of Coast Fork and Middle Fork Willamette; to contain a 100-year frequency flood (230,000 cubic feet per second at Salem with all existing, authorized, and assured projects in operation) would require excavation of 400,000,000 cubic yards of material from that same reach. Such work, particularly for the 100-year flood, would adversely affect most municipal and industrial water supply intakes, irrigation pumping installations, boat-launching ramps, and other water-based developments. It would eliminate most fish-spawning areas, and would be in conflict with the greenway concept of preserving desirable natural environment. The disposal of excavated material, the lowering of low-water surface and water table, the effect on access to the river, drainage problems behind disposal areas, and required bridge alternations would all pose problems which would have to be evaluated if this method were used. Estimated dredging costs versus flow to be contained are shown graphically in Figure IV-2 for Willamette River. Annual dredging maintenance costs, including cost of disposal, are estimated to be about 10 percent of the first cost.

To provide sufficient channel capacity for evacuation flows, construction and periodic maintenance of channel improvements would be required. Snagging, clearing, minor improvements in alignment, bank stabilization, and closures of sloughs and low overflow channels would be needed at appropriate locations. In many reaches, the existing channel capacity is adequate to meet the regulation goals as shown in Table IV-2.

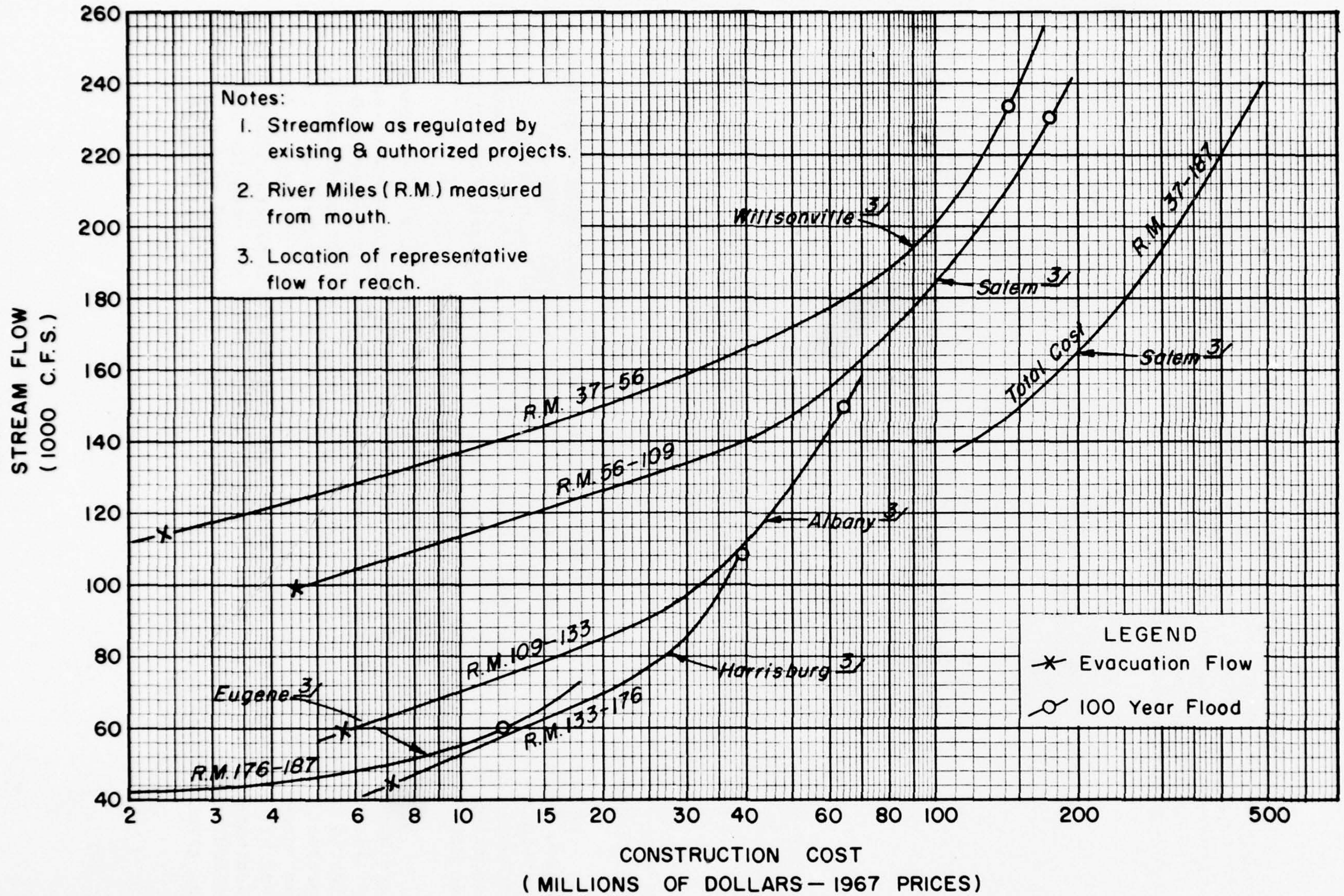


Figure IV-2 Potential channel enlargement, Willamette River

It is estimated that, in combination with other measures as appropriate, about 450 miles of tributary channel improvements would be required to meet the flood control needs of areas along tributary streams. Those improvements would cost about $10.5 million. Table IV-3 gives the general extent, by subbasins, of those tributary areas needing channel improvement.

Table IV-3
Tributary channel improvement needs

Subbasin	Reach (Miles)
Coast Fork	25
Middle Fork	5
McKenzie	-
Long Tom	40
Santiam (except Calapooia) 1/	145
Coast Range	125
Pudding	50
Tualatin	50
Clackamas	2
Columbia	8
Sandy	-
Total	450

1/ *Calapooia River needs are related to Holley Reservoir.*

Revetments are another form of channel improvement used to reduce flood damages by protection and stabilization of river banks and prevention of erosion. Control of stream meanders, and often the prevention of avulsions, can be accomplished by bank revetments and stabilization. Location of major problem areas and appropriate improvements are shown on Maps II-2a, b, and c, in Part II.

Drift barriers, usually constructed in conjunction with revetments, are another means of improving channels to reduce the damaging effects of floods. Barriers have been used to prevent or reduce deposition of debris on farmland and the adjacent flood plain, and the accompanying probability of surface scour and loss of land use. However, with the increased number of reservoirs which effectively block passage of debris, and with the completed and planned bank stabilization program which will decrease the contribution of debris to the streams, the need for additional drift barriers will be reduced. In general, consideration should be given to need for and use of drift barriers at revetment locations.

BENEFITS OF STRUCTURAL PROTECTION

Elimination of all flood damages would require that additional reservoirs, levees, and channel improvement works be constructed to control and confine all floodflows not controlled by the existing and authorized flood control system. In addition to preventing flood damages, such additional works would permit tremendous land-enhancement benefits to be realized. In the absence of flooding, the floodplain could be intensively developed, thus raising production, income, and land values. The projected incremental benefits that could be realized if such additional flood control facilities were to be constructed are shown in Table IV-4 and Figure IV-3. Those benefits would be in addition to benefits to be provided by the existing and authorized flood control system for the same period. The total benefits expected under these hypothetical conditions are shown for Willamette River and the subbasins in Table B-2, Addendum B.

Table IV-4
Projected average annual incremental benefits of complete structural protection from floods
1965 price levels

Year	Agricultural	Industrial	Community	Total
1980	$ 3,900,000	$ 400,000	$ 4,400,000	$ 8,700,000
2000	5,100,000	1,100,000	7,700,000	13,900,000
2020	9,400,000	2,600,000	15,800,000	27,800,000

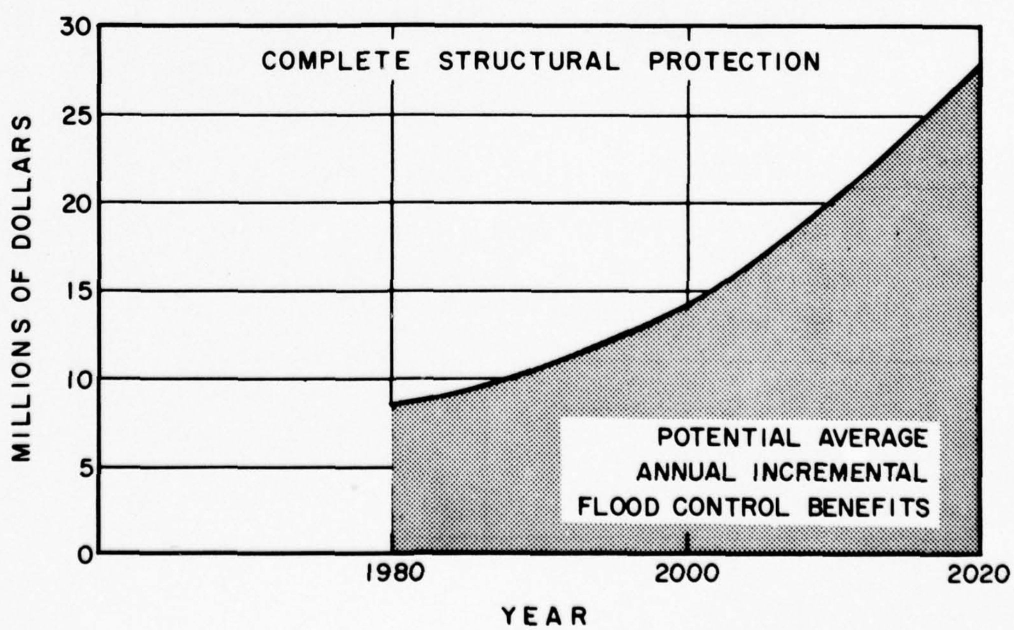


Figure IV-3 Potential Incremental Benefits of Complete Structural Protection

Additional structural protection would reduce flooding and flood damage. Joint use of storage space in additional multiple-purpose reservoirs would provide flood control benefits and permit storing water to be used for purposes such as water supply, irrigation, recreation, fish habitat improvement, and other conservation purposes during the dry season. No other potential solution to the flood problem offers this possibility.

Flood plain lands are an important resource and should be used to provide the greatest continuing advantage to the greatest number of people. To use lands subject to periodic flooding is not in itself unwarranted or inefficient because the advantages--economic and other--may far outweigh the occasional inconvenience and damage from floods. Optimum use of flood plain lands requires intelligent and practical management, including land-use and other regulation within a flexible framework which will allow for changes in demand and use.

Nationally, damage to property and human suffering resulting from floods have been increasing year by year in spite of decades of effort and the expenditure of more than $7 billion for flood control works. Figure IV-4 indicates the trend in magnitude of damages. That trend has been the consequence of rapid growth of flood-damageable improvements in the flood plains of the rivers and seacoasts. That growth has taken place at a rate which has increased overall damage potential at a rate greater than could be offset by provision of flood control works.

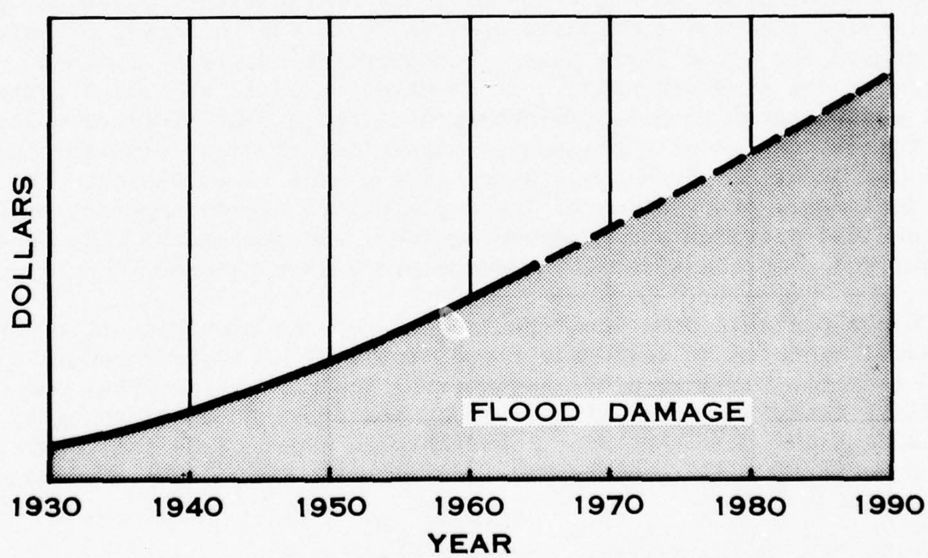


Figure IV-4 Trend in magnitude of flood damages

An obvious solution to this problem would be to exercise wisdom in the use of flood plains. However, wise use must be based on adequate knowledge of the extent and degree of flood hazard. Wise use does not mean that all uses should be excluded; rather, it means that uses which are subject to heavy damage and which can be located elsewhere should be zoned out of dangerous or flood-prone areas, and that works in flood-prone areas should be designed to withstand inundation.

FLOOD PLAIN MANAGEMENT SERVICES

Cooperative action by local, State, and Federal governments and private interests is essential to proper management of flood-prone areas. At the Federal level, greater heed is being paid to flood hazards and efforts are being made to limit the increase in flood damages. Congress in 1960 directed the Corps of Engineers to provide flood plain information to State and local governments, upon request, for their use in planning and regulating the use of flood plains (P.L. 86-845, Flood Control Act of 1960). In further recognition of increasing flood damages and the rising cost of providing flood protection by structural means, recommendations of a Presidential task force were published as H. D. 465, 88th Congress. That document contains a "Unified National Program for Managing Flood Losses." At the same time, Executive Order 11296 implementing certain recommendations in H. D. 465 was issued by the President; that Order directed Federal agencies to evaluate the flood hazard in locating Federal facilities and in disposing of Federal lands and properties. In the Flood Control Act of 1966 (P.L. 89-789), Congress widened the scope of its flood plain management policies.

Several agencies, including the Corps of Engineers, Geological Survey, Soil Conservation Service, and the State of Oregon, have been preparing flood plain information and flood plain identification studies for several years. With the recent emphasis upon the need for this type of information, the program for Flood Plain Management Services has been expanded. The purpose of the expanded program is to make available to Federal, State, and local governmental agencies information on the extent of flood hazard. This facilitates orderly planning, engineering studies, construction, and other action as may be necessary for wise use of flood plains. The program includes: preparation of flood plain information reports; provision of technical services and guidance, guides, and pamphlets; related research; and comprehensive flood damage prevention planning.

Flood plain information reports are prepared upon request of State and local agencies to delineate flood problems. A typical report includes maps or aerial mosaics; profiles; charts; tables; photographs; and a narrative describing the extent, depth, and duration of flooding by floods of the past and those that may reasonably be expected in the future. When necessary, additional physical surveys and hydrologic studies are undertaken.

It is the responsibility of State and local governmental agencies to publicize the information in the reports and to encourage use of the information by private citizens, engineering and planning firms, real estate and industrial developers, and others to whom it would be useful. Cities and counties have the further responsibility of utilizing this information in developing their zoning, subdivision, and building regulations, in order to minimize hazards to life and property from flooding.

Technical assistance is given states and local governments, upon request, in the preparation of flood plain regulations and in making decisions regarding individual flood hazards. For example, interpretation of flood data in the reports, provision of additional data, suggestions for floodway areas and evaluation of the effect of those floodways on flood heights, and related assistance are given planners and officials as they prepare and adopt flood plain regulations. Brief, preliminary flood plain information reports, where necessary, are prepared for specific sites. Necessary flood information and guidance are provided, on request, to assist in making decisions on land use regulation. Technical assistance and guidance are also given on flood proofing. Map IV-3 is an example of the maps provided by the Corps of Engineers for use in determining the extent of the flood hazard.

It is emphasized that the responsibility for adopting flood plain regulations rests with State and local governments. The Flood Plain Information Services program and other Federal activities are advisory.

BENEFITS OF FLOOD PLAIN USE REGULATION

Basin-wide local adoption of a comprehensive program of flood plain management, which includes both structural and nonstructural measures, would greatly reduce future flood damages. Under such a program, flood-plain lands would be zoned for various uses--agriculture, parks, recreation, urban and suburban areas, and industrial areas--as dictated by the likelihood of flood damage. Also, to the extent practicable, existing structures in the flood plain would be flood proofed. Other measures which could supplement the foregoing are flood insurance and perhaps increased taxation on damage-prone developments which would be commensurate with their flood-damage potential. Under such a program, the future growth of flood damages would be less than if those measures were not instituted. The projected incremental benefits that could be realized from a comprehensive program of flood plain use regulation, if added to existing and assured measures, is shown in Table IV-5 and Figure IV-5. The total benefits expected under these hypothetical conditions are shown for Willamette River and the subbasins in Table B-2, Addendum B.

Table IV-5
Projected average annual incremental benefits of flood plain use regulation
1965 price levels

Year	Agricultural	Industrial	Community	Total
1980	$ -200,000	$ 0	$ 300,000	$ 100,000
2000	-500,000	100,000	1,100,000	700,000
2020	-1,400,000	200,000	3,900,000	2,700,000

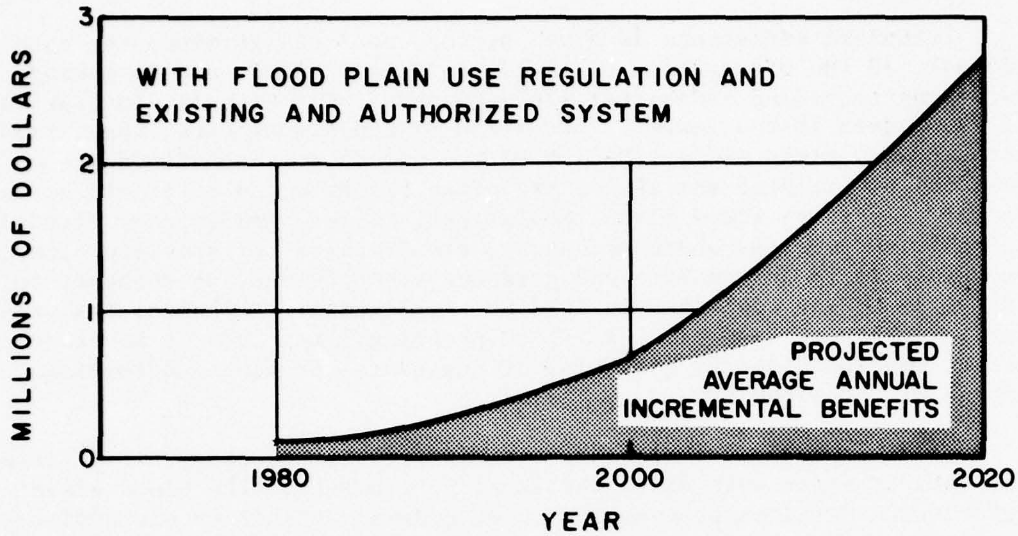


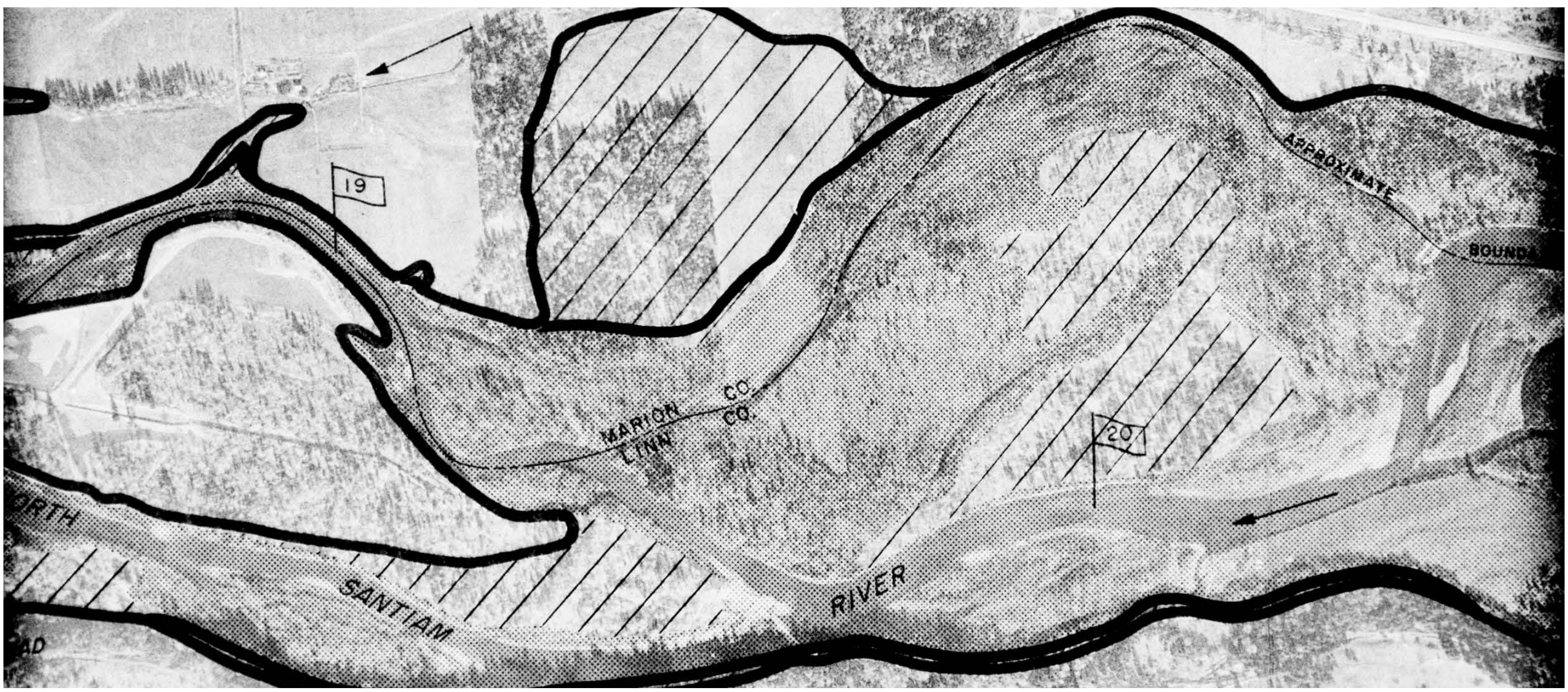
Figure IV-5 Potential Incremental Benefits of Flood-Plain-Use Regulation

Use of flood plain management measures without other measures would not eliminate all the projected flood damages and would not prevent flooding. Zoning cannot preclude the indefinite continuation of existing flood plain uses, nor can all existing uses and developments in the flood plain be rendered damage-free by flood proofing. In many areas, a substantial need for flood damage reduction would still exist, particularly in the agricultural areas. In fact, the future potential for damage to agricultural lands and improvements, as a whole, would be greater with flood plain management than without it, if no other measures were used, because additional agricultural development would occur where industrial and community developments would be zoned out. With that in mind, it is emphasized that, in plan formulation study of nonstructural measures, consideration also must be given to the costs involved and the benefits which may be foregone. Costs include those for drawing up, implementing, and enforcing zoning regulations; those which would be additional for developing and operating industries and facilities outside as compared to within the flood plain; additional transportation costs if use of the flood plain is precluded; and, perhaps most important of all in some cases, the benefits foregone and opportunity costs incurred because of single-purpose regulation versus multiple-purpose development.

WATERSHED MANAGEMENT

The masses of logging debris triggered by the 1964 flood showed that some means is needed to control this menace. Among the means available are: (1) designation, by the State Legislature, of debris as a water pollutant and therefore subject to regulation by the State Sanitary Authority; and (2) funding to fishery or other agencies for removing log and debris jams from streams. Clearing of natural growth, which acts as a drift barrier, from riparian lands should be discouraged in those areas where overbank flow would be detrimental.

4
3
D
C
B
A
22
18
19
NORTH
SANTIAM
RAILROAD
PACIFIC
SOUTHERN
KINGSTON
Match to Sheet 7
4
3



19
MARION CO.
LINN CO.
20
APPROXIMATE
BOUNDA
ORTH
SANTIAM
RIVER
OAD

LEGEND

APPROXIMATE AREA INUNDATED
BY A FLOOD WITH:

5% CHANCE OF OCCURRING IN ANY ONE YEAR. (20-YEAR FLOOD)

2% CHANCE OF OCCURRING IN ANY ONE YEAR (50-YEAR FLOOD)

1% CHANCE OF OCCURRING IN ANY ONE YEAR. (100-YEAR FLOOD)

RIVER MILE-CBIAC, JUNE 1963,
RIVER MILE INDEX

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NOTE:
FLOOD CONDITIONS ARE BASED UPON FLOWS REGULATED BY DETROIT, GREEN PETER, AND FOSTER RESERVOIRS.

LIMITS OF OVERFLOWS INDICATED MAY VARY SOME FROM ACTUAL LOCATIONS ON GROUND, AS EXPLAINED IN THE REPORT.

DATE OF PHOTOGRAPH FEBRUARY 1967

MAP IV-3
WILLAMETTE BASIN STUDY
OREGON

REPRESENTATIVE
FLOOD PLAIN
INFORMATION

1967

COMBINATION OF MEASURES

Experience has shown that structural measures for flood damage reduction have not provided a solution to the overall problem of flood damage reduction. Any practicable level of nonstructural measures, in the absence of structural measures for flood control, also probably would have failed to provide a solution. Thus, plan formulation studies should include evaluation of various combinations of structural and nonstructural measures as outlined in this appendix. In so doing, appropriate recognition should be given to the possible multiple-purpose benefits of storage used for flood control; to the costs incurred and benefits foregone for both structural and nonstructural alternatives; and to the degree of nonstructural treatment which local governments could be expected to accomplish under present and foreseeable conditions.

PART

CONCLUSIONS

CONCLUSIONS

Willamette Valley is subject to devastating floods. The 1861 flood, the earliest for which reasonably accurate data are available, is the largest flood of record. The December 1964 flood was almost as great, but downstream flows were reduced by reservoir regulation. Floods as great as these can be expected to occur only once in about 100 years on the average. Other major floods occurred in 1881, 1890, and 1923, with lesser floods occurring at more frequent intervals. Most of the floods have occurred from December through February, but occasionally in November and March.

The existing Willamette Basin project, initiated in 1938, provides about half the basin's requirements for flood-stage reduction; the project includes reservoirs to store floodwaters, bank stabilization works, channel improvements, and local works to route floods more efficiently. However, flood damages continue to rise because new improvements are constantly infringing on the flood plain, this growth stimulated in part by the reduction of the flood threat brought about by the project. Pressure for increased use of the flood plains will continue to mount as the population increases.

Flood damage reduction can be accomplished by (1) providing structural measures which will control the floods to nondamaging proportions and/or (2) regulating the use of the flood plains to purposes which will minimize losses when floods occur.

STRUCTURAL MEASURES

Effective control by reservoir storage in each of the subbasins would not necessarily provide effective control on the Willamette River, the basin's master stream. A large part of the flood-damageable improvements are situated along the Willamette River itself. The simultaneous passage of acceptable floodflows at all control stations in the subbasins would result in a flow of more than 100,000 cfs for Willamette River at Salem, even without the runoff emanating from areas downstream from the control points. The flood control storage of potential reservoirs, for consideration in plan formulation, is shown in Addendum A.

Evacuation of flood control storage is necessary for efficient operation of reservoirs. The existing Willamette River channel, and in some cases tributary channels, are presently inadequate to handle the released flows. As more reservoirs are placed in operation, the requirement will become greater and the problem more acute. Adequate channel capacities should be provided concurrently with the storage projects for efficient operation.

Channel stabilization and improvement is a complementary means of achieving flood damage reduction and providing for evacuation flow. A continuing, flexible program is most desirable so that consideration can be given to those areas having the greatest need, consistent with availability

of funds and changing conditions. It would be uneconomical and undesirable to straighten and enlarge the channel so that it could completely contain flow from major floods because of the adverse effects inherent in such undertaking. However, a limited amount of channel improvement could be accomplished to a good advantage. In some cases, material excavated to straighten channels and remove gravel bars could be used advantageously in levee construction. Obstructing gravel bars could be removed, under strict State supervision, by gravel companies at little cost to either State or Federal agencies.

Levees are another complementary means of achieving flood damage reduction which, if used alone to contain major floods, would be ineffective and undesirable. The degree and extent to which levees could be used effectively and provided economically would have to be analyzed for each specific location.

NONSTRUCTURAL MEASURES

Flood plain regulation and flood forecasting are the principal nonstructural means for flood-damage reduction. Watershed management is partly a structural and partly a nonstructural measure. Flood forecasting and watershed management techniques are applied at present and have become more and more effective as the fund of knowledge in these fields has increased. Application of flood plain regulation, on the other hand, is in a very early stage but it is rapidly gaining impetus in the basin. Additionally, the availability of flood insurance through the National Flood Insurance Act of 1968 will complement and further encourage State and local land use and control measures. As flood plain information becomes available, comprehensive planning for damage reduction in flood plain areas will become possible. Avoidance of flood-prone areas in constructing costly new improvements should be strongly encouraged. However, the land use objectives of State and local governments should largely influence the degree of regulation and other alternatives available to decrease future flood losses.

The principal need in watershed management, from a flood control standpoint, is to curtail debris. This would require programs of prohibiting its being left behind after logging and other operations and/or funding some agency to clear streambanks.

COMBINATION OF MEASURES

The exclusive use of either structural or nonstructural measures would be impractical and uneconomical. The best apparent solution to the flood problem in Willamette Basin would be to provide a combination of structural and nonstructural measures. The extent to which these measures would be respectively appropriate is shown in Appendix M - Plan Formulation.

A D D E N D U M A

This addendum contains Table A-1, which shows potential flood control storage sites, and need for additional development at existing sites. Locations are referenced to the Willamette Meridian. The storage requirements shown are those amounts necessary to completely control a 100-year flood at the site; the costs per acre-foot (1967 prices) are for the storage requirement shown. Site numbers in the table, also shown on Map IV-1 and the subbasin maps in Part IV, are those used by the Oregon State Water Resources Board. The narrative in the main body of the report relative to Table A-1 is presented in Part IV - Alternative Means to Satisfy Demands.

Table A-1

Potential flood control storage sites

Site No.	Name	Stream	Location Sec	Location Twp	Location Rng	At-Site Storage Requirement (Ac-ft)	Drainage Area (Sq mi)	Cost per Acre-ft. (Dollars)
		Subbasin 1 - Coast Fork					665	
1/	Dorena	Row River	32	20S	2W	82,500 4/	265	
1/	Cottage Grove	Coast Fork Willamette R.	28	21S	3W	29,000 4/	104	
547	Abrams	Mosby Creek	5	22S	2W	45,000	66	405
6	Cottage Grove #3	Coast Fork Willamette R.	20	22S	3W	41,500 5/	72	325
10	Disston	Row River	35	21S	1W	70,000 5/	124	380
17	North Fork (Camas Swale)	N. Fork Camas Swale Cr.	5	19S	3W	1,400	6	120
23	Unnamed	Silk Creek	30	20S	3W	3,400	11	260
25	Unnamed	Trib. to Coast Fk.	32	18S	2W	2,000	8	210
26	Unnamed	Camas Swale	8	19S	3W	4,000	17	80
		Subbasin 2 - Middle Fork					1,354	
1/	Fall Creek	Fall Creek	1	19S	1W	-	184	
1/	Hills Creek	M. Fork Willamette R.	35	21S	3E	24,000 4/	389	
1/	Lookout Point	M. Fork Willamette R.	13	19S	1W	38,000 4/ 8/	991	
32	Campers Flat	M. Fork Willamette R.	12	24S	3E	113,000	176	510
37	Little Fall Cr.	Little Fall Creek	12	18S	1E	7,700	24	100
41	Moolack Mountain	N.F. of M.F. Willamette	36	19S	5E	52,000 5/	97	560
55	Upper N. Fork	N.F. of M.F. Willamette	27	19S	4E	74,000 5/	136	295
570	Mile 56	M. Fork Willamette R.	34	22S	3E	167,000 5/	265	260
572	Unnamed	Rattlesnake Creek	13	19S	2W	530	2	200
		Subbasin 3 - McKenzie					1,342	
1/	Cougar	S. Fk. McKenzie River	31-32	16S	5E	3,000 4/	208	
1/	Blue River	Blue River	16	16S	4E	-	88	
2/	Gate Creek	Gate Creek	28	16S	2E	-	50	
61	Twisty Creek	McKenzie River	35	15S	6E	88,000	229	300
71	Foley Ridge	McKenzie River	9	16S	6E	130,000	340	500

1 of 8 sheets--footnotes on sheet 8

Table A-1 (Cont'd)

Site No.	Name	Stream	Location Sec	Twp	Rng	At-Site Storage Requirement (Ac-ft)	Drainage Area (Sq mi)	Cost per Acre-ft. (Dollars)
		Subbasin 3 - McKenzie (Cont'd)						
81	Horse Creek	Horse Creek	35	16S	6E	57,500	136	450
95	Mohawk	Mohawk River	17	17S	2W	125,000	180	250
104	Rebel Creek	S. Fk. McKenzie River	11	18S	5E	94,000 5/	119	420
114	Thurston	McKenzie River	26	17S	2W	425,000	1,130	240
116	Unnamed	Shotgun Creek	30	15S	1W	4,500	15	100
121	Upper Mohawk #2	Mohawk River	28	15S	1E	5,800	18	125
		Subbasin 4 - Long Tom					526	
1/	Fern Ridge	Long Tom River	4	17S	5W	30,000 4/	275 6/	
129	Bear Creek	Bear Creek	11	16S	6W	450	2	155
130	Bunker Hill	Coyote Creek	24	19S	5W	3,200 5/	12	165
134	Ferguson Creek	Ferguson Creek	14	15S	6W	1,600	6	170
137	Gillespie Corner	Fox Hollow Creek	13	19S	5W	2,800 5/	11	170
149	Log Pond	Elk Creek	30	17S	6W	3,600 5/	11	200
157	Poodle Creek	Poodle Creek	12	17S	7W	2,200 5/	7	80
161	Smith	Long Tom River	6	17S	6W	17,500 5/	30	395
167	Unnamed	Ferguson Creek	23	15S	6W	830	3	190
172	Noti	Long Tom River	21	17S	6W	30,000 5/	45	340
548	Battle Creek	Coyote Creek	29	18S	5W	35,000 5/	52	315
573	Unnamed	Owens Creek	35	15S	6W	1,130	4	170
		Subbasin 5 - Santiam					2,440	
		(North Santiam River)						
1/	Detroit	North Santiam River	7	10S	5E	60,000 4/	438	
179	Bear Branch	Bear Branch	28	9S	1W	3,400	11	110
186	Byars Creek	Breitenbush River	29	9S	6E	92,000 5/	104	380
188	Canyon Creek	Little N. Santiam R.	36	8S	3E	70,000	59	400

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Table A-1 (Cont'd)

Site No.	Name	Stream	Location Sec	Twp	Rng	At-Site Storage Requirement (Ac-ft)	Drainage Area (Sq mi)	Cost per Acre-ft. (Dollars)
	Subbasin 5 - Santiam (Cont'd)							
	(North Santiam River Cont'd)							
197	Elkhorn	Little N. Santiam R.	9	9S	3E	102,000	91	400
240	Tunnel	North Santiam River	20	10S	7E	170,000 5/	181	325
241	Lyons	Little N. Santiam R.	8	9S	3E	102,000	91	400
	(South Santiam River)							
1/	Foster	South Santiam River	27	13S	1E	-	494	
1/	Green Peter	Middle Santiam River	10	13S	2E	-	277	
2/	Cascadia	South Santiam River	35	12S	2E	-	179	
180	Bear Creek	Middle Santiam River	24	12S	4E	89,000 5/	87	375
190	Chimney	Middle Santiam River	20	12S	5E	65,000 5/	70	465
203	Jordan	Thomas Creek	5	10S	1E	71,000	76	170
205	Indian Prairie	Thomas Creek	15	10S	2E	47,000	46	375
226	Packers Gulch	Quartzville Creek	24	11S	3E	80,000 5/	80	595
228	Patterson	South Santiam River	35	13S	3E	70,000 5/	83	550
232	Sawmill	Crabtree Creek	22	11S	1E	56,500	66	505
235	Upper Soda	South Santiam River	26	13S	4E	56,500 5/	61	680
237	Sucker Slough	Sucker Slough	5	10S	1W	1,250	5	145
244	Unnamed	Hamilton Creek	17	12S	1E	6,000	17	110
251	Wiley Creek	Wiley Creek	7	14S	2E	48,700	51	315
	(Calapooia River)							
2/	Holley	Calapooia River	14	14S	1W	-	105	
191	Courtney Creek	Courtney Creek	22	14S	2W	2,350	9	235
224	Oak Creek	Oak Creek	1	13S	2W	1,600	5	275
243	Unnamed	Little Muddy Creek	36	14S	3W	600	2	175

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Table A-1 (Cont'd)

Site No.	Name	Stream	Location Sec	Twp	Rng	At-Site Storage Requirement (Ac-ft)	Drainage Area (Sq mi)	Cost per Acre-ft. (Dollars)
	Subbasin 6 - Coast Range						1,794	
	(North Yamhill River)							
256	Baker Creek	Baker Creek	15	4S	5W	4,800	15	100
276	Lower Fairdale	North Yamhill River	28	2S	5W	40,500	47	235
277	Upper Fairdale	North Yamhill River	29	2S	5W	8,100	25	70
292	Moores Valley	Haskins Creek	4	3S	5W	12,800	15	275
301	Panther Creek	Panther Creek	22	3S	5W	4,000	12	110
307	Pike	North Yamhill River	25	2S	5W	57,000	67	225
	(South Yamhill River)							
253	Agency	South Yamhill River	12	6S	8W	46,500	64	285
254	Agency Creek	Agency Creek	26	5S	8W	13,800	18	250
261	Buck Hollow	Willamina Creek	12	5S	7W	43,500	61	200
264	Cedar Creek	South Yamhill River	33	5S	8W	11,500	15	400
269	Gopher Valley	Deer Creek	11	5S	6W	13,500	22	275
280	Lower Ft. Yamhill	South Yamhill River	18	6S	7W	76,000	99	165
3/	Gorge	Mill Creek	8	7S	6W	25,000	31	
293	Lower Muddy Creek	Muddy Creek	17	5S	5W	4,000	12	100
318	Tindle Creek	Tindle Creek	23	5S	7W	2,200	6	185
576	Unnamed	Salt Creek	15	7S	5W	790	3	305
577	Unnamed	West Fork Salt Creek	11	7S	6W	1,050	4	295
582	Unnamed	E. Fork Willamina Cr.	5	5S	6W	3,800	12	70
583	Unnamed	Cosper Creek	32	5S	7W	2,500	7	65
584	Unnamed	Rowell Creek	17	6S	7W	4,600	12	105
585	Unnamed	Ead Creek	29	5S	8W	1,500	5	130

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Table A-1 (Cont'd)

Site No.	Name	Stream	Location Sec	Location Twp	Location Rng	At-Site Storage Requirement (Ac-ft)	Drainage Area (Sq mi)	Cost per Acre-ft. (Dollars)
		Subbasin 6 - Coast Range (Cont'd)						
		(Rickreall Creek)						
268	Dallas	Rickreall Creek	36	7S	6W	25,000	31	380
		(Luckiamute River)						
252	Airlie	Luckiamute River	15	9S	5W	152,000	236	185
260	Black Rock	Little Luckiamute R.	13	8S	7W	7,600	20	125
283	Hoskins	Luckiamute River	19	10S	6W	32,500	40	415
287	Lewisville	Little Luckiamute River	9	9S	5W	80,000	80	200
302	Pedee	Luckiamute River	33	9S	6W	93,500	115	265
316	Staats Creek	Staats Creek	4	10S	5W	560	2	100
317	Sulphur Springs	Soap Creek	34	10S	5W	2,650	10	205
321	Seekay	Luckiamute River	34	9S	7W	31,000	28	470
328	Vincent Creek	Vincent Creek	32	10S	6W	3,400	11	105
550	Teal Creek	Teal Creek	27	8S	6W	4,900	13	155
587	Unnamed	Pedee Creek	20	9S	6W	4,000	13	115
		(Marys River)						
259	Beaver Creek	Beaver Creek	11	13S	6W	2,900	11	130
299	Oliver Creek	Oliver Creek	14	14S	6W	3,450	13	130
310	Reese Creek	Reese Creek	2	14S	6W	1,620	6	120
319	Tumtum	Tumtum River	27	11S	7W	28,500	35	615
334	Wren	Marys River	29	11S	6W	72,500	78	460
574	Noon	Marys River	34	11S	6W	77,500	97	275

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Table A-1 (Cont'd)

Site No.	Name	Stream	Location Sec	Twp	Rng	At-Site Storage Requirement (Ac-ft)	Drainage Area (Sq mi)	Cost per Acre-ft. (Dollars)
		Subbasin 6 - Coast Range (Cont'd)						
		(Minor Tributaries to Willamette River)						
291	Unnamed	Middle Fk. Ash Creek	14	8S	5W	840	2	250
296	Unnamed	North Fk. Ash Creek	6	8S	5W	720	2	255
315	Unnamed	Spring Valley Creek	26	6S	4W	840	4	165
578	Unnamed	Trib. to Chehalem Cr.	33	2S	3W	340	2	420
581	Unnamed	Trib. to Chehalem Cr.	18	3S	3W	300	2	190
		Subbasin 7 - Pudding					1,186	
		(Molalla River)						
348	Dickey Bridge	Molalla River	14	5S	2E	165,000	204	170
359	North Fork	Molalla River	31	5S	3E	160,000	190	215
375	Pelkey	Molalla River	6	7S	3E	86,000	93	185
		(Pudding River)						
344	Coleman	Pudding River	4	8S	1W	940	3	215
347	Del Aire Ranch	Butte Creek	32	6S	2E	26,000	30	320
350	Ebner	Trib. to Pudding R.	10	8S	1W	1,330	5	185
351	Fisher	Drift Creek	6	8S	1E	3,200	11	85
352	Grange	Silver Creek	19	7S	1E	34,000	40	225
386	Selah	Pudding River	5	7S	1W	39,000	59	7/
569	Coal Creek	Butte Creek	30	6S	2E	30,000	35	385
593		South Fk. Silver Cr.	23	8S	1E	3,500	11	210

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Table A-1 (Cont'd)

Site No.	Name	Stream	Location Sec	Twp	Rng	At-Site Storage Requirement (Ac-ft)	Drainage Area (Sq mi)	Cost per Acre-ft. (Dollars)
		Subbasin 7 - Pudding (Cont'd)						
		(Mill Creek)						
358	Jefferson Road	Battle Creek	22	8S	3W	1,470	6	190
367	Miller	Mill Creek	3	9S	1W	2,800	11	205
407		Beaver Creek	30	8S	1W	5,650	21	110
589		North Fk. Beaver Cr.	23	8S	1W	1,260	5	230
		Subbasin 8 - Tualatin					711	
2/	Scoggins	Scoggins Creek	20	1S	4W	27,500	39	
417	Dairy Creek	East Fk. Dairy Creek	22	2N	3W	26,500	42	280
418	Forest Dale	Tualatin River	20	1S	5W	7,000	24	210
420	Gales Creek No. 1	Gales Creek	21	1N	4W	43,000	65	285
422	Gaston	Tualatin River	34	1S	4W	33,000	52	225
423	Glenwood	Gales Creek	23	2N	5W	26,500	34	330
2/	McKay Creek	McKay Creek	13	2N	3W	7,000	24	
435	Tolke Canyon	Witcher Creek	3	2N	4W	940	3	190
2/	Rock Creek	Rock Creek	24	1N	2W	5,700	19	
440	Unnamed	East Fk. Dairy Cr.	28	3N	3W	7,300	25	155
441	Unnamed	Gales Creek	20	2N	5W	4,400	14	100
443	Unnamed	McFee Creek	18	2S	2W	3,000	9	170
449	Unnamed	Trib. to W. Fk. Dairy Creek	5	2N	4W	1,400	5	230

Table A-1 (Cont'd)

Site No.	Name	Stream	Location Sec	Twp	Rng	At-Site Storage Requirement (Ac-ft)	Drainage Area (Sq mi)	Cost per Acre-ft. (Dollars)
		Subbasin 9 - Clackamas					1,014	
451	Big Bottom	Clackamas River	26	6S	7E	100,000	139	140
461	Eagle Creek	Eagle Creek	10	3S	4E	70,000	79	350
467	Clear Creek	Clear Creek	4	3S	3E	41,500	63	145
497	Unnamed	Eagle Creek	26	3S	5E	9,000	28	125
507	Upper Austin Point	Collawash River	27	6S	6E	135,000	152	135
		Subbasin 10 - Columbia					431	
510	Unnamed	Milton Creek	16	5N	2W	3,000	9	130
513	Unnamed	North Scappoose Cr.	17	4N	2W	5,800	13	130
515	Unnamed	Trib. to Johnson Cr.	26	1S	3E	920	4	215
591	Unnamed	Trib. to Johnson Cr.	19	1S	3E	980	4	380
592	Unnamed	Trib. to Johnson Cr.	19	1S	4E	910	4	380
		Subbasin 11 - Sandy					582	
526	Linney	Salmon River	18	4S	8E	29,300	54	510
541	Unnamed	Gordon Creek	7	1S	5E	5,200	16	175

1/ *Existing project*
2/ *Authorized project*
3/ *Considered part of base system*
4/ *Required in addition to existing storage*
5/ *Upstream from existing reservoir*
6/ *Includes 23 square miles of Amazon Creek drainage*
7/ *Site not physically capable of more than 22,000 acre-feet*
8/ *Does not include the 24,000 acre-feet needed at Fall Creek Reservoir*

A D D E N D U M   B

This addendum contains Tables B-1 and B-2, which show projections of flood damages and flood-damage-reduction benefits, respectively, under three assumed conditions of future development. The base year is 1965, and the projections are for 1980, 2000, and 2020. The three conditions of development are:

1. With existing and authorized flood control systems, without significant flood-plain-use regulation.

2. With existing and authorized flood control systems, plus hypothetical flood-plain-use regulation.

3. With all flood damages eliminated by hypothetical complete structural protection.

Projections are given for the entire basin, each subbasin, and for the Willamette River flood plain. The subbasin projections do not include those areas on the Willamette River flood plain lying within the respective subbasin. All projections of damages and benefits are average annual dollar amounts at 1965 price levels.

SOURCES OF DATA

Information to develop the data in Tables B-1 and B-2 includes or was derived from the following sources:

1. Historical flood damage surveys and reports by the Corps of Engineers.

2. Historical hydrological data from the United States Geological Survey, Weather Bureau, and Corps of Engineers.

3. Regional and local population projections based on the analysis in Appendix C - Economic Base.

4. Land shift projections from agricultural to other uses based on Appendix G - Land Measures and Watershed Protection.

5. Soil productivity potential, based on work by Oregon State University and the Soil Conservation Service.

6. Average annual damage data for upstream reaches provided by the Soil Conservation Service. These reaches were not included in Corps of Engineers surveys.

7. Records of cost of Willamette River dredging by Corps of Engineers.

COMPUTATION METHOD

The values are the result of computing the average annual damages, at 1965 price level, for each condition and subbasin. Computations are based on development as of 1965 and are projected to 1980, 2000, and 2020.

Growth rates vary for the projections according to assumed conditions; that is, implementation of flood plain use regulation, provision of complete structural protection, and the condition of no change from the 1965 outlook of existing and authorized structures with very little flood plain use regulation (the case in 1965). The growth rates are developed by combining individual growth determinants such as projections of population (national, basin and subbasin), projections of per capita income (basin), land shift from agricultural use (basin and subbasin), flood plain increased productivity potential (subbasin), rate of increase of agricultural productivity (national) due to drainage and reduced flooding, rate of increase of industrial productivity (basin), industrial enhancement potential (basin), and community enhancement potential (basin).

In the projections of future growth rates, flood-plain-use regulation and complete structural protection apply only to flood damage amounts in areas within the 100-year flood plain. Flood plain use regulations are not expected to be implemented outside the area of the 100-year flood plain. Also, structural protection against flood damages would not significantly affect the extent of development outside the 100-year flood plain.

Under the condition of no change from the existing and authorized flood control system and without significant flood-plain-use regulation, the above determinants apply to the growth rates for each of the following damage categories:

Agricultural = national and basin population, normal land shift from agricultural uses, and rate of increase in agricultural productivity (about 2%)

Community = subbasin population and per capita income (over 4%)

Industrial = subbasin population and rate of increase in industrial productivity (almost 5%)

Under the condition of flood-plain-use regulation covering all of the 100-year flood plain, the growth rates (applicable to damages within the 100-year flood plain) are based on the following determinants:

Agricultural = national and basin population and rate of increase in agricultural productivity (negligible land shift from agricultural uses) (about 2-1/2%)

Community = per capita income (subbasin population within 100-year flood plain assumed to cease growth) (about 2-1/2%)

Industrial = four percent

Under the condition of theoretically eliminating all flood damages, beginning in 1965, by complete structural protection, the conditional growth rates apply only to damage reduction within the 100-year flood plain and are in effect for only 15 years (until 1980). These rates are based on the following determinants:

Agricultural = national and basin population, rate of increased agricultural productivity, and <u>twice</u> the normal land shift rate from agricultural uses and soil productivity (almost 5%)

Community = subbasin population, per capita income and community enhancement potential (about 6%)

Industrial = subbasin population, increase in industrial productivity and industrial enhancement potential (about 6%)

The average annual damages are computed by subbasin for agricultural, community, and industrial categories. The computation is an integration of the discharge-damage curve and the discharge-frequency curve (in some cases, stage is substituted for discharge). Those curves are available for 30 zones in the Willamette River Basin. The discharge-damage curves are prepared from historical flood damage surveys and reports. The frequency-discharge curves are prepared from historical hydrologic data records.

Adjustments for damage data provided by the Soil Conservation Service apply only to agricultural values. Those data, in the form of equivalent annual damages amounting to $1.1 million for the basin, includes both flood damage and the effects of restricted land use. Those data are complimentary to annual agricultural damage values derived by the Corps of Engineers and are added, by subbasin, to all projected agricultural damages and to projected agricultural benefits which are due to complete structural protection.

Flooding causes changes in the river channel which hamper navigation and require dredging for correction. Without flooding, those channel changes would be minimal. Adjustment for reduced dredging is based on allocated average annual cost of Willamette River dredging by the Corps of Engineers amounting to a total of $1.6 million. This amount is added, by subbasin, to all community projected damages and to community projected benefits due to complete structural protection.

DISCUSSION

Both damages and benefits increase over time, because of population increase and technological progress. Technological progress is reflected in greater productivity, higher per capita income, and greater investment in damageable property.

Over a given period of time, benefits creditable to flood protection would increase more rapidly than would damages if no protection were provided, because flooding discourages development and reduces damage potential. However, the rate of total damage growth continues to increase, approaching nonagricultural damage growth rates as the more slowly growing agricultural damages become proportionately smaller.

In isolated instances (e.g., Subbasin 8 - Tualatin), the tables show surprising results. Assuming that land-use regulation would halt the shift from agricultural to more intensive uses within the 100-year flood plain, agricultural damages in that area would grow at a greater-than-normal rate. The increases in agricultural damages more than offset reduced nonagricultural damages for 1980 and 2000. However, the long-range desirability of land-use regulation becomes apparent by the year 2020 and can be assumed to increase thereafter.

Table B-1
Projected average annual flood damages
Willamette Basin Study Area
1965 prices

Condition and year	Average annual damages $1,000,000			
	Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$2.4	$2.8	$0.2	$ 5.4
1980	2.9	3.8	0.4	7.1
2000	3.7	6.4	1.0	11.1
2020	5.1	12.6	2.6	20.3
With existing and authorized projects plus flood plain use regulation:				
1965	$2.4	$2.8	$0.2	$ 5.4
1980	3.0	3.5	0.4	6.9
2000	4.2	5.2	0.9	10.3
2020	6.6	8.7	2.4	17.7

Table B-1 (Cont'd)
Subbasin 1, Coast Fork

Condition and year	Average annual damages $1,000 Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$ 68	$131	$ 6	$205
1980	73	156	12	241
2000	82	220	30	332
2020	103	355	71	529
With existing and authorized projects plus flood plain use regulation:				
1965	$ 68	$131	$ 6	$205
1980	75	145	12	232
2000	87	177	28	292
2020	113	239	65	417

Table B-1 (Cont'd)
Subbasin 2, Middle Fork

Condition and year	Average annual damages $1,000			
	Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$12	$207	$0	$219
1980	13	241	1	255
2000	16	327	1	344
2020	22	515	3	540
With existing and authorized projects plus flood plain use regulation:				
1965	$12	$207	$0	$219
1980	13	232	1	246
2000	16	293	1	310
2020	22	419	3	444

Table B-1 (Cont'd)
Subbasin 3, McKenzie

Condition and year	Average annual damages $1,000			
	Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$22	$320	$0	$342
1980	30	350	1	381
2000	44	420	2	466
2020	67	582	5	654
With existing and authorized projects plus flood plain use regulation:				
1965	$22	$320	$0	$342
1980	33	338	1	372
2000	53	381	2	436
2020	92	466	5	563

Table B-1 (Cont'd)

Subbasin 4, Long Tom

Condition and year	Average annual damages $1,000 Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$112	$ 204	$ 5	$ 321
1980	122	320	10	452
2000	141	602	23	766
2020	175	1,219	56	1,450
With existing and authorized projects plus flood plain use regulation:				
1965	$112	$ 204	5	$ 321
1980	140	265	9	414
2000	191	410	20	621
2020	295	676	44	1,015

Table B-1 (Cont'd)
Subbasin 5, Santiam

Condition and year	Average annual damages $1,000 Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$ 507	$501	$ 2	$1,010
1980	582	575	3	1,160
2000	719	722	6	1,447
2020	959	984	13	1,956
With existing and authorized projects plus flood plain use regulation:				
1965	$ 507	$501	$ 2	$1,010
1980	592	559	3	1,154
2000	751	681	7	1,439
2020	1,070	890	14	1,974

Table B-1 (Cont'd)
Subbasin 6, Coast Range

Condition and year	Average annual damages $1,000 Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$390	$316	$ 26	$ 732
1980	454	372	48	874
2000	564	497	101	1,162
2020	752	743	218	1,713
With existing and authorized projects plus flood plain use regulation:				
1965	$390	$316	$ 26	$ 732
1980	463	349	45	857
2000	598	424	98	1,120
2020	871	552	214	1,637

Table B-1 (Cont'd)
Subbasin 7, Pudding

Condition and year	Average annual damages $1,000			
	Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$ 363	$173	$1	$ 537
1980	464	238	1	703
2000	641	387	3	1,031
2020	947	693	7	1,647
With existing and authorized projects plus flood plain use regulation:				
1965	$ 363	$173	$1	$ 537
1980	482	210	1	693
2000	701	295	3	999
2020	1,143	444	6	1,593

Table B-1 (Cont'd)
Subbasin 8, Tualatin

Condition and year	Average annual damages $1,000			
	Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$ 489	$126	$ 5	$ 620
1980	495	164	11	670
2000	569	332	31	932
2020	694	807	93	1,594
With existing and authorized projects plus flood plain use regulation:				
1965	$ 489	$126	$ 5	$ 620
1980	562	138	9	709
2000	746	203	22	971
2020	1,119	338	54	1,511

Table B-1 (Cont'd)
Subbasin 9, Clackamas

Condition and year	Average annual damages $1,000			
	Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$14	$ 416	$0	$ 430
1980	17	600	0	617
2000	23	1,090	0	1,113
2020	35	2,236	0	2,291
With existing and authorized projects plus flood plain use regulation:				
1965	$14	416	$0	$ 430
1980	20	545	0	565
2000	31	868	0	899
2020	53	1,531	0	1,584

Table B-1 (Cont'd)
Subbasin 10, Columbia

Condition and year	Average annual damages $1,000 Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$8	$ 117	$ 8	$ 133
1980	8	216	17	241
2000	8	498	44	550
2020	8	1,212	118	1,338
With existing and authorized projects plus flood plain use regulation:				
1965	$8	$ 117	$ 8	$ 133
1980	8	165	15	188
2000	8	282	33	323
2020	8	495	75	578

Table B-1 (Cont'd)
Subbasin 11, Sandy

Condition and year	Average annual damages $1,000 Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$0	$ 36	$0	$ 36
1980	0	65	0	65
2000	0	155	0	155
2020	0	413	0	413
With existing and authorized projects plus flood plain use regulation:				
1965	$0	$ 36	$0	$ 36
1980	0	46	0	46
2000	0	76	0	76
2020	0	125	0	125

Table B-1 (Cont'd)
Willamette River Flood Plain

Condition and year	Average annual damages $1,000			
	Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$ 440	$ 290	$ 140	$ 870
1980	600	520	290	1,410
2000	880	1,190	730	2,800
2020	1,380	2,880	1,970	6,230
With existing and authorized projects plus flood plain use regulation:				
1965	$ 440	290	$ 140	$ 870
1980	650	490	280	1,420
2000	1,030	1,080	720	2,830
2020	1,800	2,490	1,930	6,220

Table B-2
Projected average annual flood-damage-prevention benefits
Willamette Basin Study Area
1965 prices

Condition and year	Equiv. annual accomplishments $1,000,000			
	Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$ 5.8	$ 13.2	$ 3.5	$ 22.5
1980	8.1	24.4	6.9	39.4
2000	11.8	54.7	17.7	84.2
2020	18.5	127.3	47.4	193.2
With existing and authorized projects plus flood plain use regulation:				
1965	$ 5.8	$ 13.2	$ 3.5	$ 22.5
1980	7.9	24.7	6.9	39.5
2000	11.3	55.8	17.8	84.9
2020	17.1	131.2	47.6	195.9
With complete structural protection:				
1965	$ 5.8	$ 13.2	$ 3.5	$ 22.5
1980	12.0	28.8	7.3	48.1
2000	16.9	62.4	18.8	98.1
2020	27.9	143.1	50.0	221.0

Table B-2 (Cont'd)
Subbasin 1, Coast Fork

Condition and year	Equiv. annual accomplishments $1,000			
	Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$235	$ 191	$ 91	$ 517
1980	305	368	188	816
2000	436	815	459	1,710
2020	731	1,771	1,099	3,601
With existing and authorized projects plus flood plain use regulation:				
1965	$235	$ 191	$ 91	$ 517
1980	303	379	188	870
2000	431	857	461	1,749
2020	721	1,887	1,105	3,713
With complete structural protection:				
1965	$235	$ 191	$ 91	$ 517
1980	382	536	201	1,119
2000	523	1,062	491	2,076
2020	843	2,184	1,176	4,203

Table B-2 (Cont'd)
Subbasin 2, Middle Fork

Condition and year	Equiv. annual accomplishments $1,000			
	Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$108	$1,000	$ 15	$ 1,123
1980	160	1,948	30	2,138
2000	246	4,363	72	4,581
2020	422	9,399	176	9,997
With existing and authorized projects plus flood plain use regulation:				
1965	$108	$1,000	$ 15	$ 1,123
1980	160	1,958	30	2,148
2000	246	4,296	73	4,615
2020	422	9,495	176	10,093
With complete structural protection:				
1965	$108	$1,000	$ 15	$ 1,123
1980	174	2,200	31	2,405
2000	263	4,612	74	4,949
2020	446	9,964	179	10,589

Table B-2 (Cont'd)
Subbasin 3, McKenzie

Condition and year	Equiv. annual accomplishments $1,000 Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$ 65	$ 227	$ 10	$ 302
1980	90	416	18	524
2000	130	869	43	1,042
2020	197	1,917	104	2,218
With existing and authorized projects plus flood plain use regulation:				
1965	$ 65	$ 227	$ 10	$ 302
1980	87	427	18	532
2000	121	908	43	1,072
2020	172	2,033	104	2,309
With complete structural protection:				
1965	$ 65	$ 227	$ 10	$ 302
1980	136	780	19	935
2000	197	1,318	45	1,560
2020	299	2,563	109	2,971

Table B-2 (Cont'd)
Subbasin 4, Long Tom

Condition and year	Equiv. annual accomplishments $1,000			
	Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$253	$ 929	$ 49	$ 1,231
1980	298	1,765	99	2,162
2000	379	3,800	237	4,416
2020	527	8,246	565	9,338
With existing and authorized projects plus flood plain use regulation:				
1965	$253	$ 929	$ 49	$ 1,231
1980	280	1,820	100	2,200
2000	329	3,992	240	4,561
2020	407	8,789	577	9,773
With complete structural protection:				
1965	$253	$ 929	$ 49	$ 1,231
1980	414	2,145	110	2,669
2000	513	4,533	262	5,308
2020	692	9,750	626	11,068

Table B-2 (Cont'd)
Subbasin 5, Santiam

Condition and year	Equiv. annual accomplishments $1,000 Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$ 679	$1,783	$ 41	$ 2,503
1980	977	2,918	72	3,967
2000	1,514	5,194	140	6,848
2020	2,457	9,246	274	11,977
With existing and authorized projects plus flood plain use regulation:				
1965	$ 679	$1,783	$ 41	$ 2,503
1980	967	2,934	72	3,973
2000	1,482	5,235	139	6,856
2020	2,346	9,340	273	11,959
With complete structural protection:				
1965	$ 679	$ 1,783	$ 41	$ 2,503
1980	1,648	3,526	75	5,249
2000	2,371	5,975	146	8,492
2020	5,898	10,335	287	16,520

Table B-2 (Cont'd)
Subbasin 6, Coast Range

Condition and year	Equiv. annual accomplishments $1,000			
	Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$ 39	$ 23	$ 10	$ 72
1980	56	40	18	114
2000	86	76	39	201
2020	136	149	84	369
With existing and authorized projects plus flood plain use regulation:				
1965	$ 39	$ 23	$ 10	$ 72
1980	48	55	21	124
2000	56	132	43	231
2020	40	304	88	432
With complete structural protection:				
1965	$ 39	$ 23	$ 10	$ 72
1980	590	458	79	1,127
2000	799	663	167	1,629
2020	1,110	1,068	360	2,538

Table B-2 (Cont'd)
Subbasin 7, Pudding

Condition and year	Equiv. annual accomplishments $1,000 Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$ 0	$ 0	$0	$ 0
1980	0	0	0	0
2000	0	0	0	0
2020	0	0	0	0
With existing and authorized projects plus flood plain use regulation:				
1965	$ 0	$ 0	$0	$ 0
1980	-(19)	28	0	9
2000	-(60)	92	0	32
2020	-(196)	249	1	54
With complete structural protection:				
1965	$ 0	$ 0	$0	$ 0
1980	511	276	1	788
2000	714	464	3	1,181
2020	1,063	849	7	1,919

Table B-2 (Cont'd)
Subbasin 8, Tualatin

Condition and year	Equiv. annual accomplishments $1,000 Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$ 0	$ 0	$ 0	$ 0
1980	34	26	0	60
2000	44	67	14	125
2020	62	182	42	286
With existing and authorized projects plus flood plain use regulation:				
1965	$ 0	$ 0	$ 0	$ 0
1980	-(33)	52	7	26
2000	-(133)	196	23	86
2020	-(363)	651	81	369
With complete structural protection:				
1965	$ 0	$ 0	$ 0	$ 0
1980	1,096	389	12	1,497
2000	1,331	883	34	2,248
2020	1,727	2,277	100	4,104

Table B-2 (Cont'd)
Subbasin 9, Clackamas

Condition and year	Equiv. annual accomplishments $1,000 Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$ 0	$ 0	$0	$ 0
1980	0	0	0	0
2000	0	0	0	0
2020	0	0	0	0
With existing and authorized projects plus flood plain use regulation:				
1965	$ 0	$ 0	$0	$ 0
1980	-(2)	55	0	53
2000	-(8)	223	0	215
2020	-(18)	705	0	687
With complete structural protection:				
1965	$ 0	$ 0	$0	$ 0
1980	25	678	0	703
2000	32	1,259	0	1,291
2020	49	2,616	0	2,665

Table B-2 (Cont'd)

Subbasin 10, Columbia

Condition and year	Equiv. annual accomplishments $1,000			
	Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$0	$ 0	$ 0	$ 0
1980	0	0	0	0
2000	0	0	0	0
2020	0	0	0	0
With existing and authorized projects plus flood plain use regulation:				
1965	$0	$ 0	$ 0	$ 0
1980	0	51	2	53
2000	0	216	11	227
2020	0	716	43	759
With complete structural protection:				
1965	$0	$ 0	$ 0	$ 0
1980	8	275	20	303
2000	8	635	52	695
2020	8	1,548	139	1,695

Table B -2 (Cont'd)
Subbasin 11, Sandy

Condition and year	Equiv. annual accomplishments $1,000 Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$0	$ 0	$0	$ 0
1980	0	0	0	0
2000	0	0	0	0
2020	0	0	0	0
With existing and authorized projects plus flood plain use regulation:				
1965	$0	$ 0	$0	$ 0
1980	0	13	0	13
2000	0	66	0	66
2020	0	254	0	254
With complete structural protection:				
1965	$0	$ 0	$0	$ 0
1980	0	83	0	83
2000	0	198	0	198
2020	0	527	0	527

Table B-2 (Cont'd)
Willamette River Flood Plain

Condition and year	Equiv. annual accomplishments $1,000			
	Agricultural	Community	Industrial	Total
With existing and authorized projects:				
1965	$ 4,462	$ 9,026	$ 3,245	$ 16,733
1980	6,147	16,911	6,509	29,567
2000	8,976	39,513	16,762	65,251
2020	13,986	96,395	45,071	155,452
With existing and authorized projects plus flood plain use regulation:				
1965	$ 4,462	$ 9,026	$ 3,245	$ 16,733
1980	6,103	16,938	6,511	29,552
2000	8,826	39,630	16,774	65,230
2020	13,563	96,782	45,118	155,463
With complete structural protection:				
1965	$ 4,462	$ 9,026	$ 3,245	$ 16,733
1980	6,984	17,464	6,797	31,245
2000	10,197	40,771	17,502	68,470
2020	15,886	99,453	47,064	162,403

END
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